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LEVEL II

A STUDY TO DETERMINE THE EFFECT OF GLASS COMPOSITIONAL VARIATIONS ON VIBRATION DAMPING PROPERTIES

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Complex modulus	Enamel-modifier	Oberst beam

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results of an experimental investigation to determine the effects certain oxide additions have on the damping properties of a commerical glass (enamel) of known composition (Corning 0010) whose damping properties had previously been characterized. One of the aims of this investigation was to determine the effect the oxide additons had on the temperature at which peak damping occurred, singly and in combination. Past experience indicated the temperature of peak damping to be

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20. related to the viscosity of the glass. The results of this investigation indicated the temperature at which peak damping occurs (peak in the loss modulus curve) is related to the viscosity of the glass. Additions which made the glass more refractory (increased the viscosity of the glass) increased the temperature at which peak damping occurred. Additions which made the glass less refractory (lowered the viscosity of the glass) lowered the temperature at which peak damping occurred. The results of the investigation are presented in tabular and graphical form.

FOREWORD

This report describes the results of an experimental investigation to determine the effects certain oxide additions have on the damping properties of a commercial glass (enamel) of known composition (Corning 0010) whose damping properties had previously been characterized. One of the aims of this investigation was to determine the effect the oxide additions had on the temperature at which peak damping occurred, singly and in combination. Past experience indicated the temperature of peak damping to be related to the viscosity of the glass. The results of this investigation indicated the temperature at which peak damping occurs (peak in the loss modulus curve) is related to the viscosity of the glass. Additions which made the glass more refractory (increased the viscosity of the glass) increased the temperature at which peak damping occurred. Additions which made the glass less refractory (lowered the viscosity of the glass) lowered the temperature at which peak damping occurred. The results of the investigation are presented in tabular and graphical form.

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SECTION I
INTRODUCTION

The ability of inorganic glasses to effectively damp metallic substrates subjected to cyclic stresses has been known for some time. Laboratory tests have shown that virtually any commercial glass that can be applied successfully to a metallic substrate will exhibit a "damping peak" at a temperature in the vicinity of the glass transformation temperature.

For several years the University of Dayton, under contracts funded by the Air Force Materials Laboratory, Wright-Patterson Air Force Base, has been investigating the vibration damping behavior of inorganic glass compositions. Nashiff,(1,2) using a commercial glass composition, showed the ability of inorganic glasses to provide damping to metal structures when the glass was operating in its transition range. Over the course of several years investigators have documented similar behavior for numerous commercial glass compositions. However, as this technique for providing vibration damping gained acceptance it became obvious that commercial glass and enamel frit compositions were not available to provide adequate damping over the entire temperature range required by the Air Force.

The primary purpose of the study reported here was to determine the effects of various oxide additions on the vibration damping characteristics of a base glass composition (Corning 0010). With the successful completion of the investigation sufficient information would be provided to guide future investigators in developing glass compositions tailored for specific Air Force needs in areas where high temperature, high cycle and fatigue problems exist.

The experimental design was influenced by basic glass structure compositional theories. These theories and other basic glass concepts will now be discussed.

The reasons for the damping phenomenon in inorganic glasses are, at this time, not well understood. However, the effect would appear to be directly related to the viscosity-temperature relationship of a particular glass. The viscosity versus temperature varies with glass composition and atomic structure of the glass. Glasses, when applied to metallic substrates, have been traditionally called porcelain or vitreous enamels. To properly discuss enamels it is necessary to define glass and discuss glass structure.

1.1 GLASS DEFINITION AND STRUCTURE

Many definitions of glass can be found in the literature. Some consider only those products prepared from inorganic materials. Others encompass both inorganic and organic compositions. Some state that a glass must be obtained as a result of supercooling a liquid. Still others regard glasses as amorphous materials that can be prepared in measurable quantities. For the purposes of this discussion we will define a glass as "an amorphous solid with no regularity in the arrangement of its constituents."

Glasses are generally formed by solidification from the melt. The distinguishing feature between a crystalline and glassy material is that a glass structure is independent of temperature. A plot of the specific volume of a crystal, liquid, and glass, is shown in Figure 1. On cooling the liquid there is a discontinuous change in volume at the melting point (T_{mp}) if the liquid crystallizes. If crystallization does not occur, the volume of the liquid will change at nearly the same rate as before until the transformation range is reached. At some point (glass transition temperature, T_g) the expansion coefficient will decrease. The glass transition temperature is defined as the temperature of the intersection of the curve for the glassy state and that for the supercooled liquid. Below T_g the glass structure does not relax at the cooling rate used. The expansion coefficient for the glassy state is usually about the same as that for the crystal. If slower cooling rates are used, the supercooled liquid range will extend to a lower temperature as shown in Figure 2.

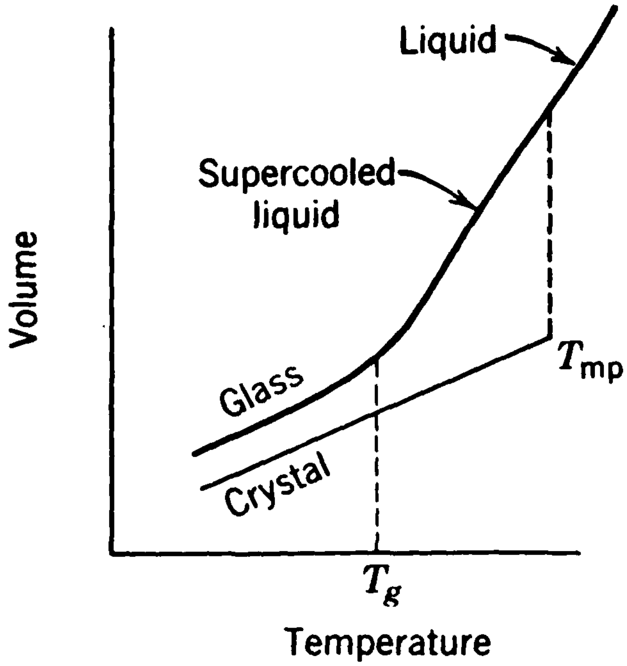

Figure 1. Specific Volume-Temperature Relations for Liquid, Glass, and Crystal.

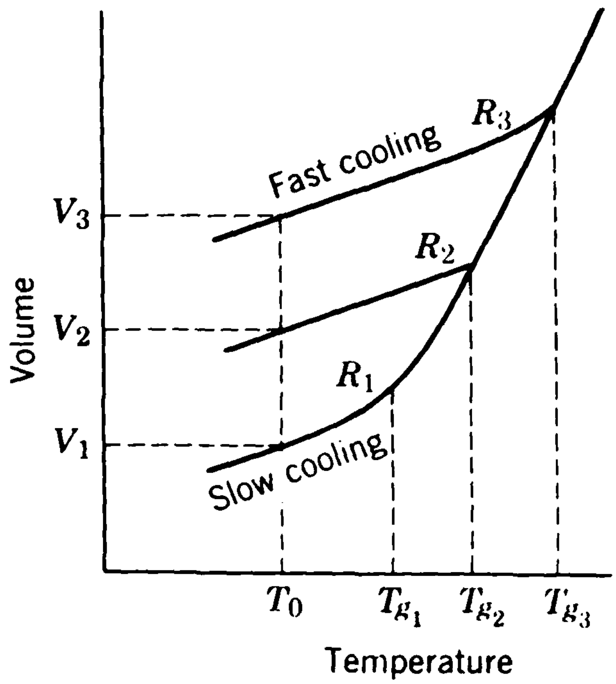

Figure 2. Specific Volume-Temperature Relations for Glasses Formed at Different Cooling Rates.

All substances of various chemical compositions, existing in the vitreous state, possess certain common properties which distinguish them from crystalline materials.

1. Glasses do not have a periodic crystalline lattice. The crystalline lattice is characterized by a periodic arrangement of repeating atomic units in certain directions at constant distances.

   The absence of an ordered crystalline lattice in glasses can be shown by x-ray diffraction analysis. A curve of intensity versus diffraction angle is similar to a liquid but exhibits a diffuse maximum. This suggests a certain "short range" order in glass systems.

2. Glasses possess excess internal energy compared with a crystalline material. Thermodynamically, glass is a metastable, non-equilibrium, system which suggests it would tend to crystallize with the evolution of heat. However, due to the excessively high viscosity of the cooled glass this does not occur.

3. Glasses have no melting point, i.e., they have no definite temperature at which the change from solid to liquid, and vice versa, takes place.

Individuals who are familiar and comfortable with crystalline materials tend to have difficulty with the structure of vitreous (glassy) solids. The task is simplified somewhat if it is understood that there are a number of different classes of glass-forming materials as shown in Table 1.[4]

TABLE 1

CLASSIFICATION OF GLASS-FORMING MATERIALS BY THE TYPE OF BONDING

Bond Type	Examples
Covalent	Oxides (silicates, borates, phosphates, etc.) Chalcogenides Organic polymers
Ionic	Halides, nitrates, carbonates, sulfates
Hydrated ionic	Aqueous solutions of salts
Molecular	Organic liquids
Metallic	Splat-cooled alloys

Enamels normally consist of alkaline silicate or alkaline borosilicate glasses of complex composition. Therefore, before examining the properties of enamels, it is convenient to discuss the covalently bonded silicate class of materials. An especially important role is played by silica glass which has received a great deal of research consideration, primarily because of its versatility and commercial importance.

Silicate glasses have no definite chemical composition like compounds. Rather, they can have their compositions varied continuously over a wide range, similar to metal alloys. It is believed that the main structure of the silicate glass (the Si-O network) is constant, but portions can be replaced or altered by

adding other oxides. Pure SiO_2, upon heating to a temperature where the material has a viscosity of approximately 10^4 poise, will polymerize to form a random chainlike network of Si and O atoms. When the temperature is dropped, supercooling of the melt occurs, crystallization cannot take place, and an amorphous solid results.

Zacharieson(5) in 1932 proposed the hypothesis of the disordered network to explain the structure of silicate and borate glasses. Glass, according to this hypothesis, consists of a continuous network similar to a continuous crystalline lattice. The network is built up of the same structural elements as in the lattice of the corresponding crystalline substance. In silicate glasses, such structural elements are tetrahedra $[SiO_4]^{4-}$. The structural elements in the continuous network of the glass are irregularly arranged, and the angles between the neighboring tetrahedra do not have constant values. Figure 3 shows the arrangement of the structure for quartz glass and crystalline quartz.

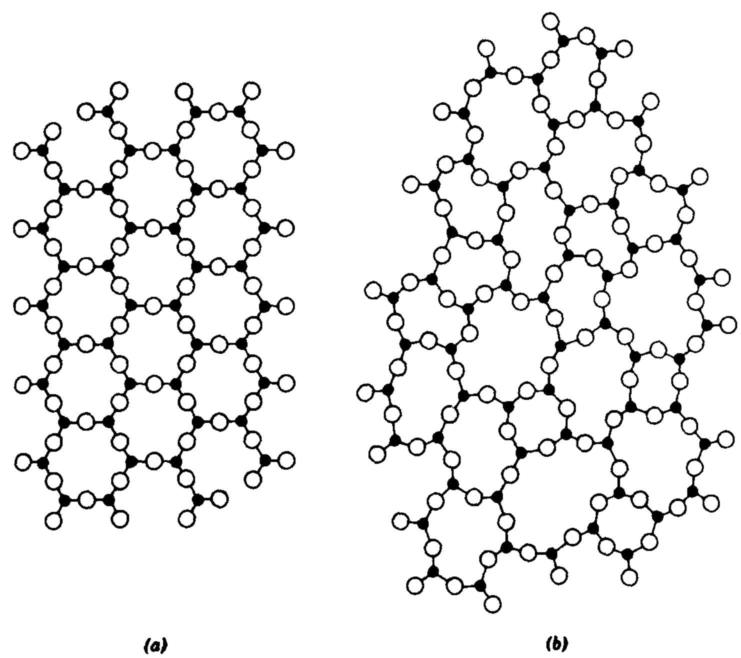

Figure 3. Representation of (a) Crystalline Silica, and (b) Random Network Glassy Silica.

Zacharieson formulated a number of conditions which must be obeyed for the oxide to exist in the glassy state: (1) The free energy of the glassy oxide A_mO_n should not be much greater than the crystalline oxide, (2) The atom of O in the structural network cannot be connected to more than two atoms of A, (3) The coordination number of the atom A should be low, and (4) With the formation of the network, the structural polyhedra can have common angles (the polyhedra should be connected by not less than three corners to adjacent polyhedra) but have no common faces or edges.

These conditions are satisfied by oxides of certain elements in groups III, IV, and V in the Periodic System: B_2O_3, SiO_2, GeO_2, P_2O_5, As_2O_5, etc. Normally these oxides are called glass-forming oxides. They can exist independently in the glassy state and also in combination with other oxides which are added to the glass, thus changing its properties. With the addition of other oxides to simple silicate glass, the oxygen from these oxides enters the network, and the cations of the added oxide find themselves in the gaps (holes). Under these conditions, ions of oxygen appear in the structure, associated only with one ion--a glass-former, the so-called non-bridged ions of oxygen. Figure 4 illustrates the structure of sodium-silicate glass, according to Zacharieson. Another oxide can be added until the conditions under which a continuous network exists are upset.

The cations easily conferring oxygen to the network of the glass have a large volume and a low charge (Li^+, Na^+, K^+, Ca^{2+}, and Ba^{2+}). These cations, called modifiers of the lattice, are distributed in the cavities of the network in a disordered manner. The cations having a high charge and low radius in some cases may enter the structural network of the glass together with the main glass formers.

Another group of oxides, called intermediates, can replace the network formers to a limited extent. Aluminum oxide (Al_2O_3) is commonly used to replace Si in the glass structure. The use of intermediates usually results in a more viscous (high damping temperature) and chemically durable glass.

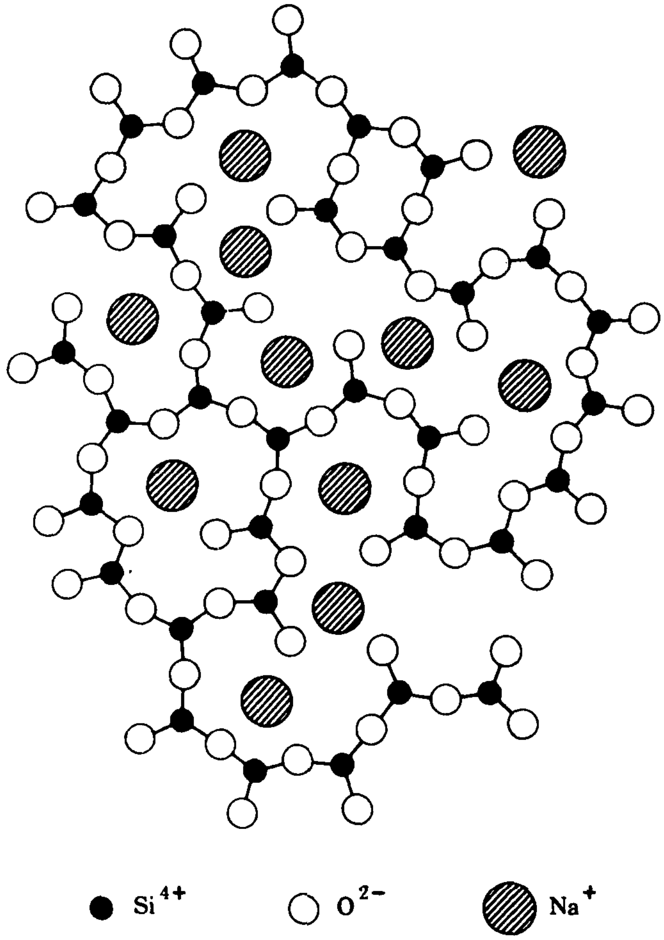

Figure 4. Structure of Sodium-Silicate Glass.

The possible combinations of oxide additions to glasses are virtually limitless. However, many of the additions are used only in very small amounts to provide subtle changes in electrical, optical, color, or adherence properties.

The Zacharieson hypothesis was subsequently further developed by many scientists (6-8). On the basis of the investigations of the physicochemical properties of glasses of varying compositions, these workers considered in greater detail the conditions of glass formation, the connection between various phenomena, and the change in coordination numbers of the ions in the glass.

Further discussion of glass structure is beyond the scope of this investigation. However, the investigators were continually aware of the importance of glass structural considerations and the necessity for correlating them with the observed vibration damping properties of the materials studied.

1.2 DAMPING PROPERTIES OF INORGANIC GLASS

A limited amount of theoretical work has been reported concerning structure versus relaxation processes in glass systems (6). Most of the experimental work has been concerned with the near-room-temperature alkali ion relaxation processes in silicate glasses at low frequencies. However, it is known that large-scale relaxations of the whole glass structure occur in the transformation range. These relaxations are attributed to noninstantaneous volume changes and the release of stresses. It has been suggested that viscous flow is the primary relaxation mechanism operating in the transition region (9,10). The theories used to try to explain this behavior have been grouped into two general types: (a) the modified Arrhenius theories, and (b) the free volume theories (6,11-13). The modified Arrhenius treatments are all similar and consist of an expression of the type:

$$\eta_s = Ae^{B/T} + Ce^{D/T}$$

where B is the energy barrier for the flow process, while D contains both B and an activation energy for configurational change.

These treatments generally try to take into account the change in size of a flowing unit or to install another activation process in order that the data can be fitted to other than a straight line in the glass transition region.

Several investigators have proposed free volume theories in an attempt to provide a satisfactory fit to the experimental data. Doolittle(14) proposed an expression for the viscosity of the type

$$\eta = e^{(V-V_o)/kT}$$

where V_o = initial free volume
V = free volume

and, because it led to the WLF equation (15) that is used extensively in the analysis of our vibration data, it is mentioned here.

Until adequate theories are devised to explain the experimental data it seems proper to assume that the explanation of the glass damping behavior is related to the viscoelastic behavior of a glass in its transition region and is further complicated by the changes in free volume of the glass in this temperature interval.

SECTION II
EXPERIMENTAL DESIGN

Enamels are quite simply glass coatings on metal substrates. In the classical sense they also contain finely dispersed crystalline phases that give the material opacity, reflectance, and in some cases color. The crystalline phase is not a requirement for enamels and may or may not be beneficial when enamels are used as a vibration damping material.

The choice of enamel compositions for vibration damping requires consideration of many factors. The properties of major importance are: (1) the temperature-viscosity relation, (2) metal-glass interface chemistry, (3) the thermal expansion coefficient, (4) the elastic modulus, and (5) the chemical and structural durability.

Of these, the temperature-viscosity relation is of primary importance in determining the temperature at which maximum damping is achieved, or alternatively, the degree of damping which may be achieved at a given temperature.

In practical applications the thermal expansion and chemical bonding match between the metal substrate and the enamel are of equal importance. These two factors control the strength of the interfacial bond (adherence).

Virtually all commercial glasses, regardless of composition, exhibit the same temperature-viscosity relationship. The difference between glasses is the particular temperature at which a given viscosity is obtained. The value of viscosity required to achieve maximum damping is not known, but is suspected to be above the "transformation range" of the glass. A complicating factor in determining the temperature of maximum damping is the temperature shift with frequency. Although this is a well known phenomenon, the magnitude of the shift is dependent on glass composition and this dependence is not well understood.

Therefore, a glass composition must be designed which has physical properties that match those of the substrate and at the same time has a temperature range for maximum damping that straddles the desired operating temperature. Past experience has shown that the temperature for maximum damping can be systematically controlled via judicious compositional modification of commercially available glasses. Also, the adherence can be modified to optimize the chemical and thermal durability.

The base glass composition chosen for this study was Corning 0010. Previous damping studies had provided sufficient data to confirm that this particular commercial glass possessed peak damping intermediate in the temperature range 300-900°C (600-1,600°F) of interest for Air Force engine applications. Also, the composition of the 0010 glass was such that various oxides could be added, within limits, without causing devitrification. The adjusted compositions of the Corning 0010, after additions of Al_2O_3 and Na_2O, are shown in Table 2. Due to the small amount (1 and 2 weight percent) of Co_2O_3 added, the adjusted composition for the glasses containing these additions was not determined.

TABLE 2

ACTUAL OXIDE COMPOSITION OF EACH GLASS AFTER Al_2O_3 AND Na_2O ADDITIONS TO CORNING 0010 BASE GLASS

Glass and Weight % Addition	SiO_2	Al_2O_3	Na_2O	K_2O	PbO
0010	63	1	7	7	22
0010 + 7.5 Al_2O_3	59	8	7	7	20
0010 + 15% Al_2O_3	55	14	6	6	19
0010 + 3 Na_2O	61	1	10	7	21
0010 + 6 Na_2O	59	1	12	7	21
0010 + 7.5 Al_2O_3 + 3 Na_2O	57	8	9	6	22
0010 + 15 Al_2O_3 + 3 Na_2O	53	14	8	6	19
0010 + 7.5 Al_2O_3 + 6 Na_2O	56	7	11	6	19
0010 + 15 Al_2O_3 + 6 Na_2O	52	13	11	6	18

Three oxides, Al_2O_3, Na_2O, and Co_2O_3, were chosen as compositional additives to the base glass for the purpose of altering its vibrational damping properties. The specimen designations and weight percent additions for all the test specimens are shown in Table 3.

TABLE 3

SPECIMEN NUMBER DESIGNATION AND CORRESPONDING WEIGHT PERCENT ADDITIONS TO CORNING 0010 GLASS

Specimen Number	Additions Al_2O_3 (Wt. %)	Na_2O (Wt. %)	Co_2O_3 (Wt. %)
M30	0	0	0
M1	7.5	0	0
M36	15.0	0	0
M2	0	3.0	0
M19	0	6.0	0
M17	7.5	3.0	0
M29	15.0	3.0	0
M49	7.5	6.0	0
M32	15.0	6.0	0
M26	0	0	1.0
M12	7.5	0	1.0
M21	15.0	0	1.0
M35	7.5	3.0	1.0
M24	15.0	3.0	1.0
M11	7.5	6.0	1.0
M22	15.0	6.0	1.0
M14	0	3.0	1.0
M48	0	6.0	1.0
M5	0	0	2.0
M27	7.5	0	2.0
M41	15.0	0	2.0

TABLE 3 (CONTINUED)

Specimen Number	Additions Al_2O_3 (Wt. %)	Na_2O (Wt. %)	Co_2O_3 (Wt. %)
M31	7.5	3.0	2.0
M4	15.0	3.0	2.0
M45	7.5	6.0	2.0
M46	15.0	6.0	2.0
M6	0	3.0	2.0
M7	0	6.0	2.0

Aluminum oxide was chosen because of its known ability to act as an intermediate oxide. Also, its valance of three causes it to introduce 1.5 oxygens per network-forming ion, causing non-bridging oxygens to be tied up and converted to bridging ions. This results in a more tightly bonded structure with more chemical durability, high viscosity, and lower thermal expansion. Therefore, Al_2O_3 was expected to increase the temperature of maximum damping at a particular frequency.

The network modifier, Na_2O, was added to reduce the temperature of maximum damping because of its ability to lower the viscosity of a glass with respect to temperature.

The additions of Co_2O_3 were made due to the known positive effect Co has on the adherence of many commercial enamels. Its effect on the damping behavior of the Corning 0010 glass was anticipated to be intermediate compared to Al_2O_3 and Na_2O.

The actual oxide compositions after additions of the oxides to the 0010 glass are also shown in Table 2.

2.1 SPECIAL EXPERIMENTAL APPARATUS

Experiments to measure the dynamic response of specimens at elevated temperature are difficult and require sophisticated techniques, especially when making measurements using the

resonant dwell technique. Devices such as accelerometers to measure the vibrational response are usually large, costly, and in some cases require external cooling apparatus. Also, the large accelerometers influence the dynamic response of the specimen. Strain gages can be used, but are effective only for measuring one or two modes of vibration, because the surface strains of the higher modes of vibration tend to be small. Due to these difficulties, it is usually best if the response can be measured by a device capable of measuring the response over a wide frequency range, mounted outside the furnace in which the specimen is being tested. Also, exciting the specimen into resonance at elevated temperatures is difficult to accomplish.

A unique apparatus was required to measure the dynamic response of glass-coated beams at elevated temperatures. The apparatus was designed and fabricated to determine the response of five to six modes of a cantilever beam over a temperature range of 25 to 1,000°C and a frequency range from 100 to 1,500 Hz.

SECTION III
TECHNICAL PROCEDURES

3.1 EXPERIMENTAL

3.1.1 Glass Preparation

The 0010 base glass was purchased from Corning* in fritted (powdered) form. The required amounts of glass and oxide additions were weighed-out on a pan balance. The weighed powders were then mechanically mixed in a V-blender for approximately one hour. The batch sizes were 450 grams each. The mixed material was then contained in a platinum crucible, heated to 1,538°C (2,800°F) for 48 hours, and quenched by pouring into a container of cold water. The quenched glass was then dry ball milled, using Al_2O_3 grinding media, for 24 hours. The milled powder was then screened to obtain various particle size splits. For the test beams prepared for the test matrix the distribution of particle sizes was obtained by passing the powder through a 100-mesh screen and using what remained on a 150-mesh screen.

3.1.2 Method of Coating Application

Prior to spraying, the metal substrate was sand-blasted using 36-mesh silicon carbide grit and an air pressure of 75 psi. The powder material was applied to the metal substrate by plasma spraying. A Meteo 3MB plasma spray apparatus was operated at 400 amps DC, 75 volts DC at 30,000 watts setting with a gas flow of 15 scfh H_2 and 80 scfh Ar. A gas mixture of 84.2% Ar and 15.7% H_2 was used. The coated beam was then fired in a resistance-heated furnace for approximately three minutes or until the surface appeared to be smooth.

3.1.3 Vibration Damping Measurements

An apparatus and technique was developed to accurately and reliably excite and measure the response of a beam specimen at temperatures exceeding 1,000°C.

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*Corning Glass Company, Corning, New York.

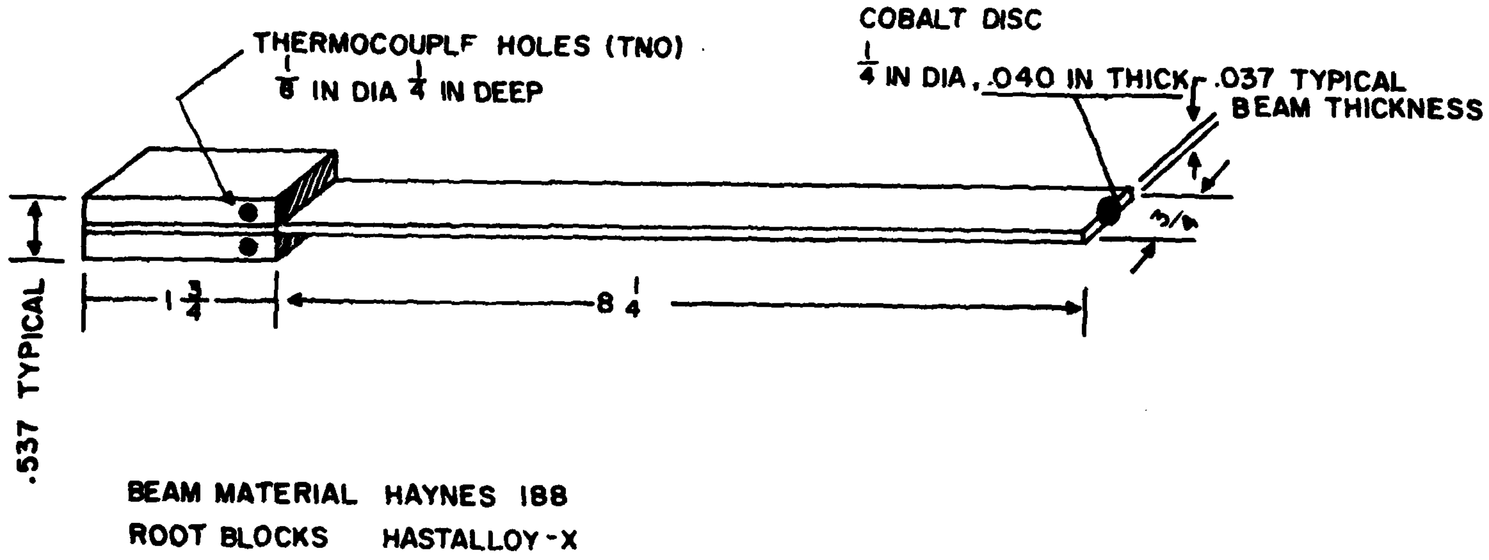

Figure 5. Typical Cantilever Beam Specimen for High Temperature Damping Material Evaluation.

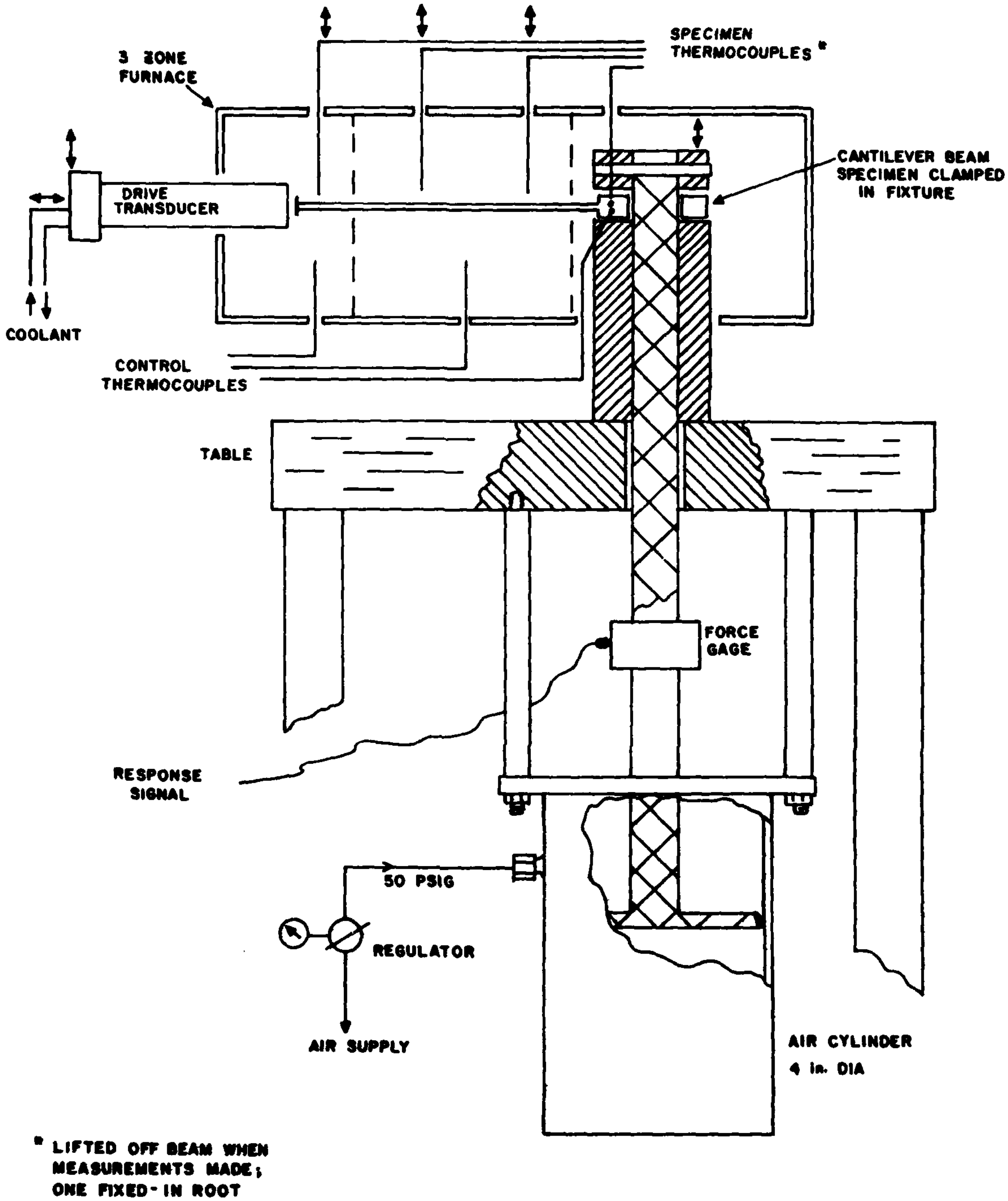

Figure 6. High Temperature Damping Test Apparatus.

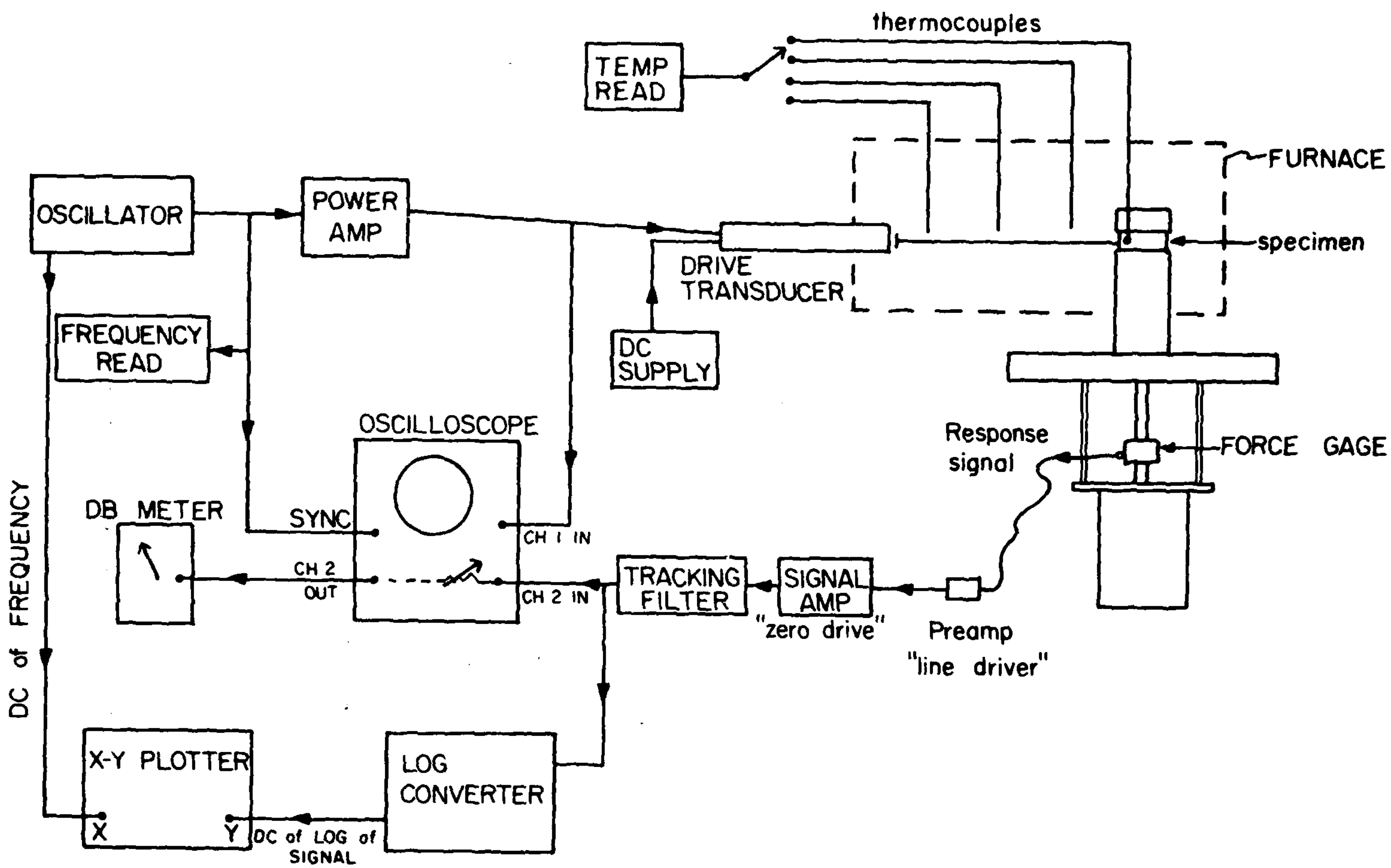

Figure 7. Schematic of High Temperature Damping Drive Transducer Power Supply and Data Recording System.

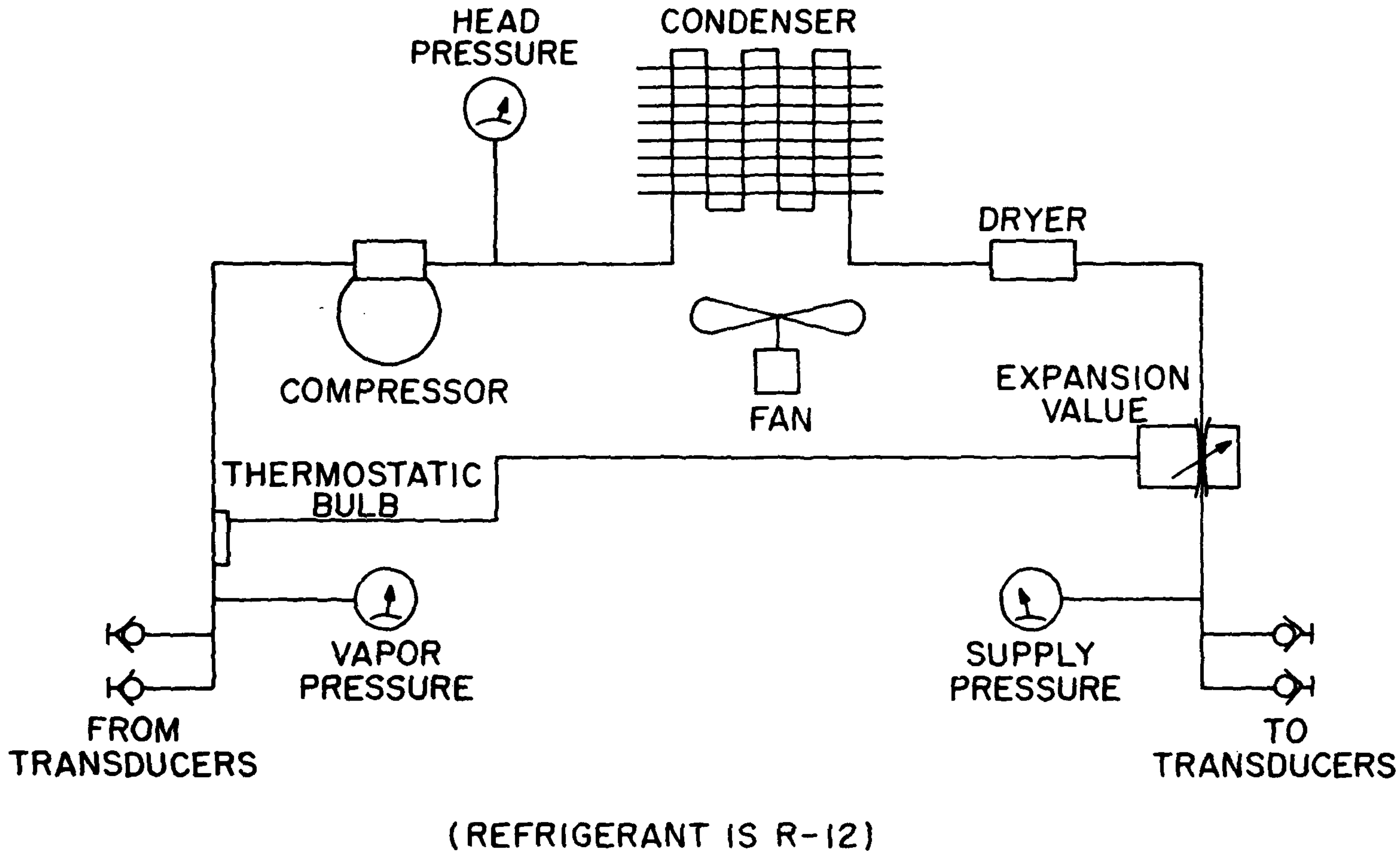

Figure 8. Schematic of High Temperature Damping Test Apparatus Cooling System.

The specimen used was a cantilever beam coated on one side with an enamel or glass. A typical specimen is illustrated in Figure 5. The specimen was clamped in the fixture as illustrated in Figure 6. The air cylinder insured that a constant clamping pressure was maintained on the root section of the specimen over the entire temperature range. This fixture also allowed for thermal expansion of the fixture and high temperature creep of the clamping bolts.

The force gage, mounted in line with the clamping bolt and the air cylinder, was used to measure the response of the specimen. The force gage was well removed from the high temperature environment.

An electromagnetic transducer was used to excite the specimen. This transducer was specially designed to operate from room temperature to at least 1,000°C. The design used a closed loop cooling system incorporating a modified room air conditioner. A block diagram of the apparatus and complete measuring system is shown in Figure 7, and Figure 8 is a schematic of the transducer cooling system.

The specimen and fixture were placed in the furnace and heated to the desired temperature, usually above the annealing temperature of the enamel. The cantilever beam specimen was excited at its free end by a sinusoidally varying magnetic force induced by the electromagnetic transducer. A high Curie temperature cobalt disc was attached to the end of the beam to allow for excitation of the nonmagnetic specimens. The frequency of oscillation was varied until a resonance was detected. At resonance the shear force in the beam reached a maximum and was measured by the dynamic force gage. The force gage measured the variation of the shear force at the root of the cantilever beam specimen.

3.2 CALCULATION OF DAMPING PROPERTIES

The damping characteristics of the coatings were determined by measuring the vibration response of a composite cantilever beam at varying temperatures over the viscoelastic range. It is

assumed that the enamel is a viscoelastic material; that is, the modulus of the enamel can be treated as a complex quantity

$$E_D^* = E_D' + iE_D'' = E_D\ (1 + i\tan\delta)$$

$$\eta_2 = \tan\delta = E_D''/E_D'$$

where E_D' is the storage or Young's Modulus of the enamel and $\tan\delta$ is the ratio of the dissipative modulus, E_D'', to the storage modulus.

Consider the metal beam with an enamel coating on one side as shown in Figure 9.

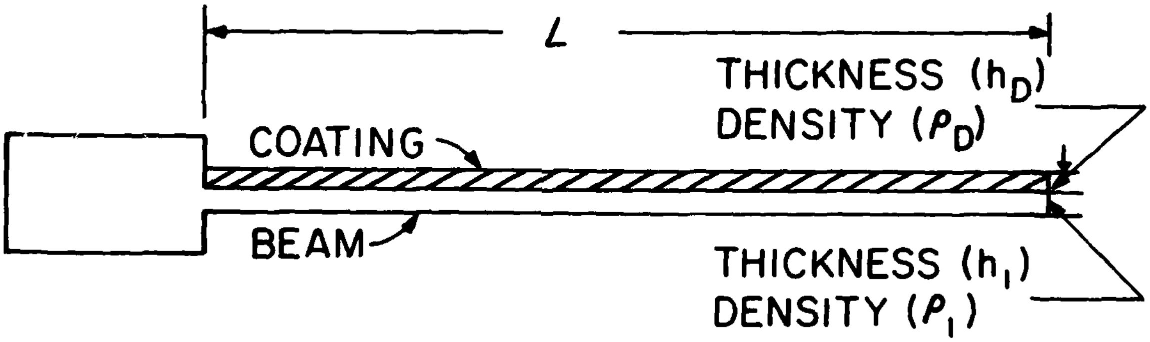

Figure 9. Coated Oberst Test Beam.

The formulas developed by Oberst (16) and used by many other investigators were used to determine the damping properties of the enamel as a function of frequency and temperature. These formulas are:

$$(\omega_n/\omega_{1n})^2(1+h_D\rho_D/h_1\rho_1) = \frac{1 + 2(E_D/E_1)(h_D/h_1)A + (E_D/E_1)^2(h_D/h_1)^4}{1 + (E_D/E_1)(h_D/h_1)} \quad (1)$$

and

$$\frac{\eta}{\eta_2} = \frac{(E_D/E_1)(h_D/h_1)[2A+2(E_D/E_1)\ (h_D/h_1)^3 + (E_D/E_1)^2(h_D/h_1)^4 -1]}{[1+(E_D/E_1)\ (h_D/h_1)][1+2A(E_D/E_1)(h_D/h_1)+(E_D/E_1)^2(h_D/h_1)^4]} \quad (2)$$

where:

$$A = 2 + 3(h_D/h_1) + 2(h_D/h_1)^2. \quad (3)$$

ω_n = natural frequency of the nth mode of the composite beam, $2\pi f_n$, rad/sec

ω_{1n}= natural frequency of the nth mode of the metal beam, $2\pi f_{in}$, rad/sec

h_D = thickness of enamel coating applied to composite beam

h_1 = thickness of metal beam

ρ_D = density of enamel coating

ρ_1 = density of metal beam

E_D = real part of the modulus of enamel coating

E_1 = Young's modulus of metal beam

$\tan\delta_e$ = effective loss factor of composite beam (= η)

$\tan\delta$ = loss factor of enamel coating (= η_2)

The quantities of h_D, h_1, ρ_D, and ρ_1 are known and are assumed to remain constant with temperature. The parameters ω_n, ω_{1n}, and η are experimentally measured. The value of η is determined from

$$\eta = \tan\delta_e = \frac{\Delta\omega_n}{\omega_n} = \frac{\Delta f_n}{f_n} \quad (4)$$

where Δf_n is the bandwidth at the half-power points of the response peak for the nth mode. The value of E_1 can be determined from the measured response of the uncoated metal beam using

$$\xi_n^4 = \mu_1 \omega_{1n}^2 L^4 / E_1 I_1 \tag{5}$$

where:

ξ_n^4 = the eigen value corresponding to the nth mode and is a constant, determined by the boundary conditions

$\mu_1 = \rho_1 b h_1$ = the mass per unit length of the metal beam

L = the length of the beam

$I = \frac{1}{12} b h_1^3$ = the second moment of area of the metal beam about its centerline.

The values of ξ_n^4 for beam with classical boundary conditions are well known and can be found in reference 17. Thus, from the measured resonant frequencies of the coated and bare beams and the measured composite loss factor, tan δ_e, the damping properties of the enamel can be determined as a function of temperature and frequency.

The resonant frequencies and modal damping of five to six modes of the coated beam, covering a frequency range of 100 Hz to 1,500 Hz, can usually be measured for each temperature. Thus, the damping properties of the vitreous coating over a decade of frequency at a given temperature can be easily and quickly determined.

SECTION IV

PRESENTATION OF RESULTS

The modal damping and resonant frequencies versus temperature for each beam were determined before the beam was coated by measuring the half-power bandwidth of the resonance. The calculated properties for the coating depend on accurate measurements of the resonant frequencies and damping of the uncoated and coated beams. Usually, the damping of the uncoated metal beams is insignificant, but experiments have shown for the type of metal alloy (Haynes 188) used in this study the damping of the metal beams starts to become significant at temperatures above 650°C (1,200°F). The damping versus temperature for modes 2, 3, 4, 5, and 6 for Haynes 188 is illustrated in Figure 10. As shown, the damping starts to peak at 950°C (1,750°C). This is especially noticeable for the second mode. Other authors have attributed this behavior to fixture damping (18). These results indicate the metal behaves as a viscoelastic material and the modal damping is related to the creep behavior of the material.

To account for the damping of the metal at temperatures above 650°C (1,200°F), the loss factor of the bare metal was subtracted from the measured loss factor of the coated beam for each mode. Sridharan (19) has shown, for thin coatings, the damping due to the coating is $\eta_C = \eta_S - \eta_B$, where η_S is the measured specimen damping and η_B is the damping measured for the uncoated beam.

The maximum values of η_D and E''_D and the temperature at which this occurs for 100 Hz and 1,000 Hz for the coatings are summarized in Table 29. The actual experimental data and the calculated damping properties of the individual coatings are presented in Tables 4 through 28.

To present the results in a form that represents both the temperature and frequency dependence of the damping properties

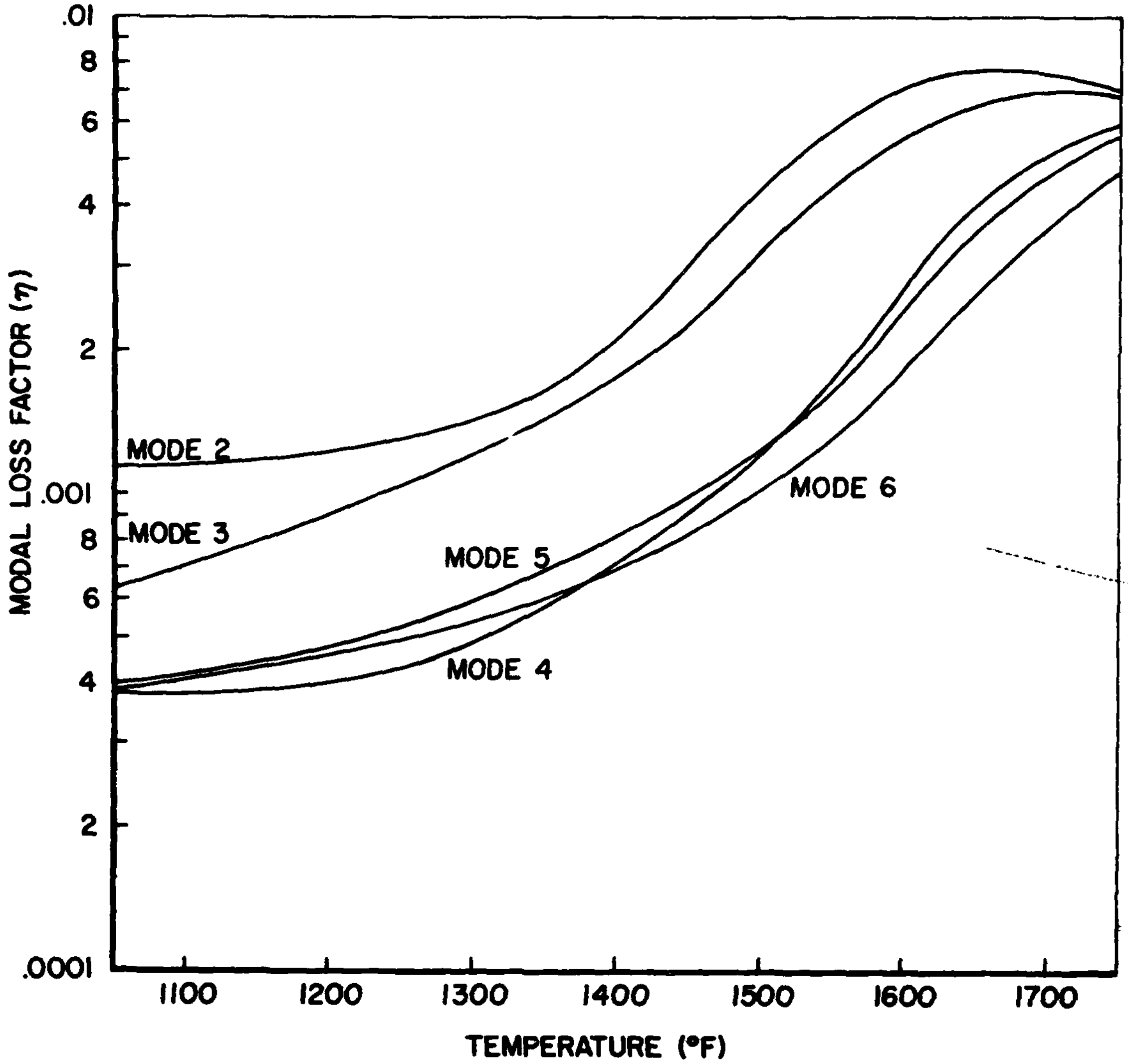

Figure 10. Modal Loss Factor Versus Temperature for Haynes 188 Alloy.

of the coatings, a nomograph developed by Jones (20) is used. A computer program has been developed by King (21), using the technique of Nashif and Rogers (22) to plot the properties on the Jones nomograph. Figures 11 through 64 illustrate the properties of the different coatings versus reduced frequency and temperature. There are two graphs for each coating. One plot is the storage and loss modulus versus reduced frequency, and the other is the storage modulus and loss factor versus reduced frequency. These plots readily illustrate the variation of the damping properties of the coating with frequency and temperature.

The plot is read by choosing the temperature of interest and following the oblique temperature isotherm until it intersects with the frequency of interest (on the right-hand side of the plot), and then reading vertically the properties at the specified temperature and frequency.

From these graphs the maximum values of the loss modulus and loss factor were determined for each coating and these values were plotted versus the additions of Al_2O_3 and Na_2O for each of the Co_2O_3 additions. Figures 65 through 67 are plots of the change in maximum loss modulus versus Al_2O_3 and Na_2O additions for zero percent, one percent, and two percent additions of Co_2O_3. Figures 68 through 70 are plots of the maximum loss factor versus Al_2O_3 and Na_2O additions for zero, one, and two percent additions of Co_2O_3 to the Corning 0010 Glass. The temperatures at which the maximum loss factor and loss modulus occurred at 100 Hz and 1,000 Hz for each of the coatings were also determined. The effect of the Al_2O_3 and Na_2O additions for zero, one, and two percent Co_2O_3 weight additions on the temperature which the maximum loss modulus occurs at 100 Hz and 1,000 Hz is illustrated in Figures 71 through 73. The results are summarized in Table 29.

It is evident from these figures that increasingly larger additions of Al_2O_3 result in a corresponding increase in temperature at which peak damping occurs. Conversely, increasing

TABLE 4

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M30

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1500	2	86.93	84.75	84.35	85.18	0.83	.00979	.0057	2.33	0.54	1.047	.1860
	3	243.40	238.20	237.39	239.10	1.70	.00715	.00507	2.41	0.699	0.942	.1350
	4	478.00	468.20	466.24	470.08	3.80	.00819	.00676	2.41	0.735	1.263	.1720
	5	793.80	776.30	771.96	779.91	7.95	.0102	.00867				
	6	1186.40	1155.40	1155.00	1168.63	13.60	.0118	.0108	2.44	0.545	1.869	.341
1450	2	87.65	85.65	85.33	85.98	0.65	.00754	.00439	2.37	0.633	1.129	.1730
	3	245.20	240.30	239.33	241.36	2.03	.00846	.0069	2.44	0.762	1.250	.1640
	4	481.50	472.30	469.88	474.68	4.80	.0102	.00905	2.45	0.798	2.233	.2150
	5	797.60	783.20	776.82	788.02	11.20	.0143	.0130				
	6	1195.00	1174.10	1164.96	1182.17	17.21	.01466	.0138	2.48	0.852	3.179	.3720
1400	2	88.37	86.44	86.14	86.93	0.79	.00918	.00654	2.41	0.664	1.253	.1830
	3	247.10	242.40	241.24	243.74	2.49	.0103	.00908	2.48	0.812	1.755	.2160
	4		476.70	473.08	479.89	6.81	.0143	.0134				
	5		799.90	803.20	796.60	6.60	.0160	.0149				
	6	1203.50	1184.40	1163.20	1199.30	36.10	.0305	.0300	2.51	0.968	5.488	.5650
1350	2	89.08	86.97	86.57	87.49	0.92	.0106	.00837	2.45	0.685	1.630	.2300
	3		244.70	242.94	246.65	3.70	.0151	.0142				
	4	498.50	481.10	475.08	486.45	11.40	.0236	.0229	2.63	0.208		
	5		796.00	788.46	807.04	18.60	.0233	.0224				
	6	1212.20	1201.50	1173.31	1225.20	51.93	.0432	.0426	2.55	1.23	8.90	.7190
1300	2	89.77	87.91	87.34	88.61	1.27	.0144	.0125	2.49	0.746	2.482	.3220
	3	250.80	247.70	244.52	250.98	6.46	.0261	.0252	2.56	1.10	5.184	.4680
	4	492.00	487.80	482.65	492.49	9.84	.0393	.0387	2.56	1.51	8.139	.5380
	5	815.20	800.30	796.20	811.50	15.20	.0371	.0364				
	6	1221.00	1224.50	1187.14	1258.24	71.10	.0580	.0574	2.59	1.78	12.309	.6890
1250	2	90.41	88.86	87.33	90.23	2.40	.0269	.0252	2.52	0.90	5.127	.5510
	3	252.55	252.60	259.31	247.69	11.60	.0460	.0467	2.59	1.65	10.389	.6290
	4	495.60	505.10	502.77	511.12	8.35	.0322	.0316	2.56	2.58	11.804	.4600
	5		803.30	799.68	810.90	11.20	.0272	.0265				
	6	1230.00	1262.70	1222.50	1295.30	72.84	.0577	.0571	2.63	2.84	13.307	.4670
1200	2	91.04	91.46	89.27	93.54	4.30	.0467	.0451	2.56	1.91	11.937	.6060
	3	254.35	260.60	253.87	270.31	16.44	.0631	.0624	2.63	2.91	15.672	.5380
	4	499.00	512.80	508.21	520.40	12.22	.0465	.0459	2.63	3.66	12.031	.3280
	5		805.70	802.44	811.75	9.31	.0225	.0218				
	6	1238.80	1300.40	1266.90	1325.00	58.10	.0447	.0441	2.66	3.97	11.130	.2800
1150	2	91.47	95.71	94.04	98.49	4.46	.0908	.0894				
	3	256.10	270.80	253.62	265.04	11.42	.0422	.0415	2.67	4.34	14.172	.3270
	4	502.60	531.24	517.39	526.62	9.23	.0339	.0333	2.67	4.33	8.522	.1970
	5	833.00	889.20	880.36	898.47	18.10	.0204	.0197	2.68	4.82	5.067	.1050
	6	1247.50	1331.90	1322.90	1344.99	22.00	.0166	.0159	2.69	4.84	7.821	.1610

TABLE 4 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M30

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1100	2	92.25	98.11	96.96	100.43	3.47	.0689	.0676	2.62	4.61	18.184	.3820
	3	257.70	275.90	273.64	278.65	5.02	.0355	.0349	2.70	5.06	9.214	.1830
	4	505.80	536.40	533.76	539.14	5.38	.0196	.0190	2.70	4.56	5.019	.1100
	5	838.00	900.80	889.92	908.51	18.60	.0206	.0200	2.72	5.38	3.136	.0582
	6	1255.50	1349.90	1344.40	1365.38	30.98	.0230	.0223	2.73	5.35	5.055	.0939
1050	2	92.83	99.86	98.67	103.27	4.60	.0461	.0449	2.66	5.30	12.63	.2310
	3	259.30	280.00	277.67	283.09	5.42	.0193	.0188	2.73	5.60	5.294	.0946
	4	509.00					.0131	.0127				
	5		912.60	906.21	917.77	11.56	.0127	.0120				
	6	1263.00	1367.60	1359.20	1375.93	16.73	.0122	.0115				
1000	2	93.30	101.00	100.68	101.50	0.84	.0161	.0151	2.69	5.60	4.346	.0751
	3	260.70	283.20	281.83	284.75	2.93	.0103	.00977	2.76	6.00	2.833	.0472
	4	508.90	558.80	556.27	561.55	5.30	.00945	.0089				
	5	847.50	922.70	919.37	925.93	6.55	.00710	.00642	2.78	6.15	1.998	.0324
	6	1270.00	1362.20	1378.55	1388.31	9.76	.00706	.00631	2.80	6.19	1.928	.0310
950	2											
	3											
	4											
	5	852.00	935.00				.0048	.0045	2.81	6.71	1.326	.0204
	6											
900	2	94.21	102.86	102.63	103.17	0.54	.00525	.0043				
	3	263.20	288.30	287.21	289.00	1.30	.0045	.0039				
	4	516.70	568.10	566.54	569.48	2.90	.00517	.00457				
	5	865.50	938.40	936.60	940.30	3.70	.00394	.00324				
	6	1280.00	1404.50	1401.70	1407.80	6.10	.00436	.00356				

TABLE 5

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M1

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1600	3	246.00	243.70				.0085		2.34	1.14	2.879	.1610
	4	483.00	478.50				.0134		2.34	1.15	4.557	.2530
	5	801.00	792.50				.0160		2.36	1.10	2.454	.3160
	6	1199.00	1187.50				.0230		2.36	1.14	7.927	.4380
1550	2	87.50	87.28				.0090		2.24	1.38	3.087	.1370
	3	247.90	245.90				.0128		2.37	1.21	4.420	.2310
	4	486.70	482.40				.0230		2.38	1.18	7.954	.4270
	5	807.00	801.00				.0245		2.39	1.25	8.560	.4340
	6	1207.70	1205.50				.0320		2.40	1.51	11.460	.4790
1500	2	88.28	85.32				.0217		2.28	0.11		3.8500
	3	249.80	248.80				.0207		2.41	1.42	7.348	.3300
	4	490.40	488.30				.0380		2.42	1.41	13.530	.6100
	5	813.00	813.00				.0353		2.43	1.61	12.800	.5040
	6	1217.00	1225.00				.0430		2.44	1.92	16.030	.5260
1450	2	89.80	87.23				.0065		2.36	0.321		.4160
	3	251.75	252.80				.0320		2.45	1.82	12.050	.4210
	4	494.00	496.20				.0490		2.45	1.83		.6280
	5	819.00	828.90				.0440		2.47	2.21	16.790	.4820
	6	1226.00	1250.00				.0490		2.47	2.57	19.280	.4720
1400	2	90.53	87.34				.00195		2.40	0.0434		.9220
	3	253.60	257.90				.0420		2.48	2.46	16.370	.4220
	4	497.70	506.50				.0500		2.49	2.50		.4960
	5	825.10	849.70				.0470		2.50	3.12	19.200	.3900
	6	1235.00	1280.00				.0440		2.51	3.46	18.480	.3360
1350	2	91.30	87.40				.0027					
	3	255.40	263.70				.0450		2.52	3.26	18.640	.3610
	4	501.40	518.30				.0390		2.53	3.34	16.270	.3080
	5	831.10	870.90				.0412		2.54	4.10	18.030	.2760
	6	1244.00	1304.00				.0288		2.55	4.13	12.720	.1940
1300	2											
	3	257.35	269.60				.0376		2.56	4.11	16.540	.2540
	4	505.00	530.70				.0260		2.56	4.29	11.590	.1700
	5	837.10	886.00				.0290		2.58	4.73	13.290	.1770
	6	1253.00	1323.80				.0175		2.58	4.63	8.036	.1090
1250	2											
	3	259.25	275.00				.0240		2.60	4.89	11.150	.1440
	4	508.70	541.00				.0162		2.60	5.05	7.607	.0950
	5	843.10	896.30				.0145		2.61	5.05	13.780	.0852
	6											
1200	2											
	3	261.10	279.60				.0134		2.63	5.53	6.508	.0740
	4	501.40	545.10				.0125		2.62	5.34	5.989	.0707 (1)
	5	849.00	905.50				.0067		2.65	5.32	3.236	.0383
	6	1270.40	1354.70				.0060		2.65	5.32	2.917	.0344

TABLE 5 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M1

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1150	2											
	3	262.90	282.80				.0074		2.67	5.89	3.697	.0395
	4	513.80	551.70				.0074		2.65	5.74	3.656	.0401 (2)
	5	855.00	914.00				.0037		2.69	5.54	1.826	.0206
	6											
1100	2											
	3	264.65	285.40				.0041		2.71	6.13	2.092	.0215
	4	517.40	556.80				.0044		2.69	5.96	2.200	.0234 (3)
	5	860.80	921.70				.00245		2.72	5.72	1.232	.0136
	6	1287.40	1377.20				.00245		2.73	5.66	1.236	.0137
1050	2											
	3	266.30	287.50				.00245		2.74	6.28	1.271	.0127
	4	520.30	561.20				.00275		2.72	6.17	1.414	.0144 (4)
	5	866.30	928.00				.00178		2.76	5.82	0.908	.00178
	6	1295.00	1386.30				.00178		2.76	5.77	0.911	.00987
1000	2											
	3											
	4	524.20	565.00				.00175		2.76	6.22	0.911	.0092 (5)
	5											
	6											
900	2	96.70	104.04				.00053		2.74		0.281	

(1) @ 1225 °F
(2) @ 1175 °F
(3) @ 1125 °F
(4) @ 1075 °F
(5) @ 1025 °F

TABLE 6

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M36

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1750	2		91.88	91.34	92.41	1.08	.0117	.0076	2.14	2.90	4.30	.1480
	3		256.30	255.20	257.90	2.65	.0103	.00463				.0932
	4		505.20	502.60	507.80	5.20	.0103					
	5		838.20	833.54	842.60	9.06	.0108					
	6		1255.20	1249.40	1260.90	11.50	.00916					
1700	2	91.88	92.40	91.63	92.88	1.24	.01345	.00705	2.19	2.47	4.02	.1620
	3	256.60	258.90	257.35	260.39	3.02	.0117	.00535	2.25	2.43	3.17	.1080
	4	505.10	509.10	506.60	512.20	5.55	.01091	.00551	2.27	2.83	3.27	.1160
	5	838.10	844.20	839.80	848.80	9.05	.0107	.00607	2.28	2.77	3.63	.1310
	6	1254.80	1265.30	1259.90	1271.00	11.00	.00873	.00493	2.30	2.92	2.97	.1010
1650	2	92.60	93.08	92.54	93.58	1.04	.01116	.00376	2.22	2.46	2.17	.0884
	3	258.90	261.51	260.25	262.94	2.70	.01031	.00471	2.29	3.11	2.85	.0915
	4	509.30	514.72	512.30	517.22	4.66	.00905	.00500	2.30	3.20	3.05	.0950
	5	844.90	853.50	849.40	856.60	7.20	.00844	.00504	2.32	3.17	3.09	.0974
	6	1264.90	1277.10	1272.90	1282.10	9.14	.00716	.00451	2.33	3.12	2.76	.0889
1600	2	93.50	94.18	93.65	94.69	1.04	.0110	.00422	2.26	2.75	2.50	.0910
	3	261.20	264.60	263.46	265.75	2.28	.00863	.00433	2.33	3.53	2.69	.0762
	4	513.60	520.16	518.27	522.30	4.03	.00775	.0052	2.34	3.52	3.24	.0922
	5	852.00	862.30	859.18	864.90	5.72	.00664	.00459	2.36	3.46	2.88	.0831
	6	1275.40	1290.30	1286.50	1294.10	7.50	.00581	.00416	2.37	3.43	2.62	.0764
1550	2	94.32	95.38	94.89	95.78	0.89	.0093	.00379	2.31	3.28	2.32	.0706
	3	263.50	267.20	266.45	268.17	1.71	.00642	.00347	2.37	3.72	2.20	.0591
	4	517.80	525.40	523.83	526.84	3.01	.00573	.00405	2.38	3.82	2.58	.0677
	5	859.00	870.80	868.43	872.98	4.55	.00522	.00382	2.40	3.73	2.45	.0657
	6	1285.40	1303.00	1300.10	1306.00	5.94	.00456	.00342	2.41	3.74	2.20	.0569
1500	2	95.16	95.95	95.60	96.28	0.68	.0071	.00325	2.35	2.98	2.00	.0673
	3	265.70	269.50	268.74	270.16	1.42	.00528	.00328	2.41	3.82	2.12	.0554
	4	521.90	529.90	528.57	531.04	2.47	.00466	.00354	2.42	3.96	2.30	.0560
	5	865.70	878.00	876.12	879.82	3.70	.00421	.00319	2.44	3.94	2.08	.0541
	6	1295.10	1313.50	1311.10	1316.00	4.80	.00368	.00284	2.45	3.86	1.86	.0481
1400	2	96.75	97.99	97.71	98.24	0.53	.00539	.00335	2.42	3.65	2.16	.0593
	3	270.10	274.00	273.51	274.51	1.009	.00367	.00245	2.49	3.96	1.63	.0412
	4	530.00	538.50	537.58	539.32	1.74	.00323	.00259	2.49	4.18	1.74	.0416
	5	892.30	879.00	890.87	893.81	2.94	.00330	.00256	2.51	4.09	1.72	.0422
	6	1315.60	1334.40	1332.80	1335.80	3.03	.00227	.00171	2.52	3.99	1.16	.0289
1300	2	98.19	99.50	99.30	99.68	0.38	.00383	.00225	2.50	3.83	1.50	.0392
	3	278.40	274.20	278.09	278.70	0.61	.0022	.00134	2.57	4.20	0.924	.2200
	4	538.00	546.80	546.30	547.35	1.05	.00191	.00137	2.57	4.35	0.948	.0218
	5	892.00	905.70	904.90	906.62	1.72	.00190	.00123	2.59	4.24	8.54	.0202
	6	1334.80	1354.30	1353.20	1355.00	1.83	.001354	.00085	2.60	4.16	5.92	.0142

TABLE 7

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M19

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1500	1		13.68	13.48	13.83	0.349	.0255	.01450				
	2		83.84	83.08	84.68	1.60	.0141	.01560				
	3	246.94	242.30	241.79	242.77	0.98	.00405	.00240	2.43	0.634	6.499	.1030
	4	485.80	475.70	474.79	476.62	1.86	.0034	.00230	2.44	0.510	0.708	.1270
	5	804.20	787.90	786.47	789.36	2.89	.0037	.00279	2.45	0.561	0.832	.1370
	6	1204.00	1180.90	1178.55	1183.15	4.60	.0039	.00302	2.46	0.623	0.863	.1380
1400	1		13.84	13.65	14.04	0.39	.0280	.01900				
	2	89.42	87.51	87.69	88.05	0.36	.0041	.00204				
	3	250.70	246.10	245.68	246.55	0.88	.00356	.00253	2.50	0.642	0.786	.1230
	4	493.00	483.10	482.11	484.14	2.03	.0042	.00300	2.51	0.568	0.950	.1540
	5	816.20	800.00	798.28	801.92	3.65	.00456	.00390	2.52	0.559	1.366	.2250
	6	1222.00	1198.80	1195.81	1202.34	6.57	.0055	.00494	2.53	0.659	1.483	.2240
1350	1											
	2											
	3	252.50	247.90					.00340	2.54	0.697	1.006	.1440
	4	822.20	806.00					.00600	2.56	0.613		.2960
	5	1230.00	1209.50					.00730	2.56	0.799	1.932	.2910
	6	1230.00	1209.50					.00730	2.56	0.799	2.208	.2740
1300	1		14.23	14.12	14.32	0.20	.0141	.00760				
	2	90.69										
	3	254.25	250.00	249.30	250.69	1.36	.00545	.00466	2.57	0.775	1.445	.1870
	4	500.00	491.00	489.05	493.02	3.98	.00810	.00711	2.59	0.724	2.307	.4380
	5	828.00	813.21	808.87	817.53	8.66	.0107	.01020	2.60	0.735	3.195	.4040
	6	1238.80	1222.30	1217.88	1229.56	11.68	.0186	.01820	2.60	1.001	3.715	.3680
1250	1											
	2											
	3		252.30	251.70	253.54	2.37	.0094	.00870				
	4	503.50	496.10	492.59	499.78	7.20	.0145	.01350	2.62	0.954	4.431	.4380
	5	833.70	822.50	814.40	830.22	15.80	.0192	.0187	2.63	1.02	5.593	.5170
	6	1247.80	1244.90	1232.89	1258.65	25.80	.0207	.02030	2.64	1.54	6.758	.4370
1200	1											
	2	91.98										
	3	257.80	255.30	253.16	257.45	4.30	.0168	.01620	2.64	1.27	5.126	.4050
	4	507.00	503.20	500.20	506.15	5.95	.0231	.02220	2.66	1.39	8.266	.5750
	5	839.30	835.40	829.05	841.61	12.60	.0294	.02900	2.67	1.59	10.578	.6520
	6	1256.20	1265.20	1250.86	1305.65	54.80	.0433	.04300	2.67	2.40	13.554	.5600
1150	1		15.23	14.91	15.14	0.23	.0151	.01450				
	2		91.03	90.26	91.78	1.52	.0166	.01540				
	3	259.60	259.70	255.71	263.82	8.05	.0310	.03040	2.68	1.91	10.067	.5280
	4	510.20	518.60	506.20	534.93	28.90	.0557	.05490	2.69	3.06		.6150
	5	844.60	852.70	837.03	868.43	31.40	.0547	.05430	2.70	2.60		.7240
	6	1265.00	1294.20	1279.10	1311.48	32.40	.0488	.04850	2.71	3.53	17.832	.5010

TABLE 7 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M19

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1100	1		16.26	16.12	16.50	0.38	.0234	.01790				
	2											
	3	261.20	265.60	261.28	270.75	9.47	.0356	.03510	2.71	3.01	12.261	.4080
	4	513.40	528.60	519.64	537.84	18.20	.0512	.05040	2.73	3.99		.4600
	5	850.00	873.20	880.45	865.95	14.50	.0324	.03200	2.74	3.79		.3270
	6	1273.00	1319.20	1300.22	1343.54	43.30	.0328	.03250	2.75	4.44	12.097	.2710
1050	1		15.90	15.58	1.623	0.64	.0404	.03540				
	2											
	3	262.76	270.86	267.40	274.84	7.44	.0275	.02690	2.75	4.16	10.027	.2410
	4	516.50	535.20	541.30	530.00	11.30	.0211	.02190	2.76	4.59		.1830
	5	855.00	887.70	883.00	893.02	10.00	.0113	.01090	2.77	4.70		.1100
	6	1280.50	1328.40	1319.96	1340.30	20.35	.0153	.01500	2.78	4.68	5.781	.1230
1000	1	14.24	15.68	16.18	15.17	1.01	.0642	.06400				
	2	94.32										
	3	264.30	275.50	273.13	277.88	4.70	.0171	.01660	2.78	5.07	6.419	.1270
	4	519.50	542.00	538.71	545.23	6.52	.0120	.01130	2.79	5.11		.0860
	5	860.00	898.00	892.14	902.53	10.40	.01157	.01120	2.74	3.79		.0658
	6	1288.00	1341.90	1336.90	1348.25	11.35	.00846	.00820	2.78	4.68	3.473	.0680
950	1		18.73	19.05	18.42	0.63	.0337	.03320				
	2		101.10	100.16	102.54	2.38	.0235	.02250				
	3	265.83	279.20	277.91	280.54	2.63	.00941	.00890	2.81	5.68	3.577	.0630
	4	522.40	548.50	546.63	550.75	4.12	.00752	.00684	2.82	5.67		.0490
	5	865.50	908.40	905.20	911.20	5.94	.00654	.00622	2.84	5.66		.0456
	6	1294.20	1354.10	1348.10	1358.10	10.07	.00744	.00719	2.84	5.40	2.559	.0470
900	1	14.68										
	2	95.30										
	3	266.97	281.85					.00520	2.84	6.15	2.142	.0350
	4	525.00	555.00					.00520	2.85	6.29		.0340
	5	869.00	916.00					.00500	2.86	6.07		.0340
	6	1300.50	1366.00					.00500	2.87	5.60		.0350

TABLE 8

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M17

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1600	1	14.06	13.68	13.58	13.79	0.214	.0156	.0018	2.33			
	2	88.51	86.37	85.84	86.75	0.91	.0104					
	3	244.10	241.70	240.26	243.40	3.15	.0130	.00853	2.37	0.572		.0895
	4	487.70	477.10	475.38	478.72	3.35	.0070	.00437	2.38	0.298	0.728	.2440
	5	807.50	791.00	788.02	793.97	5.94	.00751	.00570	2.38	0.388		.4590
	6	1209.00	1184.20	1179.20	1189.48	10.24	.00865	.00720	2.40	0.394	2.44	.6190
1500	1	14.35	14.00	13.90	14.11	0.207	.0148	.00230	2.43	0.143		.4720
	2		88.20	87.40	88.60	0.701	.00795					
	3	252.60	243.90	242.41	247.89	5.48	.0225	.02080	2.45	0.663		.2850
	4	495.70	485.90	483.49	487.80	4.32	.00888	.00745	2.46	0.440	2.24	.5090
	5	821.00	805.50	800.70	811.40	10.70	.0133	.01230	2.46	0.572		.7070
	6	1228.70	1208.60	1198.04	1219.21	21.18	.0175	.01660	2.47	0.689	2.78	.4040
1450	1	14.48	14.12	14.04	14.22	0.189	.0134	.00240				
	2	90.92	89.12	88.65	89.45	0.793	.0089					
	3	254.60	248.20	246.22	250.23	4.01	.0162	.01500				
	4	499.68	489.30	485.11	492.44	7.30	.0150	.01400				
	5	827.40	815.80	807.62	823.18	15.56	.01410	.01830				
	6	1238.20	1226.70	1208.90	1242.70	33.80	.0276	.02690	2.55	1.46	8.20	.5530
1400	1	14.62	14.24	14.15	14.32	0.17	.0120	.00290	2.52	0.0391		.2760
	2		89.70	89.16	90.17	1.01	.0113					
	3	256.60	251.70	250.43	252.42	1.99	.0154	.01450	2.53	1.17		.5780
	4	503.50	497.80	494.68	501.30	6.62	.0260	.02530	2.53	1.13	6.64	.5880
	5	834.00	824.90	814.66	836.19	21.50	.0261	.02550	2.54	1.12		.8010
	6	1248.00	1242.10	1230.77	1245.33	14.60	.0117	.00111	2.52	2.26	8.40	.3730
1350	1		14.38	14.29	14.47	0.184	.0128	.00620				
	2		90.40	89.33	91.00	1.67	.0185					
	3	258.50	253.40	255.28	251.81	3.47	.0137	.01290	2.56	1.86		.6070
	4	507.40	505.40	498.03	513.80	15.76	.0312	.03060	2.57	1.74	10.20	.5870
	5	840.50	842.70	825.42	854.77	29.35	.0348	.03430	2.58	1.66		.7430
	6	1257.40	1262.00	1257.50	1270.49	12.94	.0103	.00980	2.60	2.45	11.70	.4780
1300	1	14.88	14.59	14.46	14.71	0.253	.0173	.01120	2.61	5.02		.8650
	2		90.46	87.63	91.63	4.00	.0440					
	3	260.50	255.10	253.61	257.00	3.39	.0133	.01260	2.60	2.78		.5280
	4	511.20	515.40	506.70	526.04	19.35	.0315	.03710	2.60	2.50	12.50	.5060
	5	846.80	858.50	844.59	812.07	27.50	.0321	.02270	2.66	4.21		.4310
	6	1366.80	1390.70	1273.89	1312.85	38.97	.0301	.02820	3.06	3.81	13.00	.3400
1250	1	14.99	15.04	14.83	15.31	0.479	.0319	.0264	2.65	1.45		.6750
	2	93.73										
	3	262.40	275.70	255.24	259.24	4.00	.01555	.01490	2.64	3.89		.3550
	4	515.50	525.10	530.70	510.26	20.40	.03894	.03850	2.65	3.34	10.90	.3270
	5	852.80	878.40	870.55	889.36	18.80	.0214	.02110	2.66	4.21		.2150
	6	1275.50	1312.70	1297.86	1325.56	27.70	.0211	.02070				

TABLE 8 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M17

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1200	1	15.10	15.32	15.04	15.77	0.728	.04753	.04240	2.69	3.01		.5560
	2											
	3	264.20	259.20	257.43	260.51	3.08	.0119	.01130	2.68	4.91		.2080
	4	518.60	531.20	525.02	534.56	9.54	.0180	.01760	2.69	4.32	7.53	.1740
	5	858.70	890.20					.01360	2.69	4.90		.1190
	6	1276.00	1330.00	1320.00	1338.40	18.40	.0138	.01350	2.67	4.18	4.96	
1150	1	15.22	15.80	16.27	0.793	0.0502	.0454	.04500	2.73	4.87		.4000
	2											
	3		261.40	260.47	262.29	1.82	.00695	.00640				
	4		542.10	538.91	544.74	5.83	.0107	.01040				
	5		898.90	895.42	903.26	7.85	.00873	.00846				
	6		1345.60	1340.50	1350.40	10.90	.0074	.00708				
1100	1	15.32	16.34	16.14	17.10	0.955	.0583	.0538	2.77	6.26		.2200
	2	95.67										
	3	267.80	263.40	262.80	264.00	1.19	.04504	.00400	2.75	6.09		.0612
	4	525.50	548.00	546.12	549.70	3.57	.00651	.00616	2.76	5.46	2.49	.0460
	5	870.00	908.10	905.88	910.17	4.29	.00472	.00448	2.76	5.58		.0378
	6	1301.60	1358.60	1355.40	1361.47	6.09	.00448	.00419	2.78	5.50	2.70	.0310
1000	1	16.49	16.69	16.60	16.80	0.204	.0122	.00850	2.84	7.53		.0453
	2											
	3	270.90	266.90	266.50	267.31	0.812	.00304	.00257	2.82	6.64		.0185
	4	531.70	556.90	556.08	557.51	1.43	.00256	.00224	2.83	5.93	1.06	.0180
	5	880.20	921.60	920.64	922.51	1.87	.00203	.00182	2.83	5.90		.0140
	6	1316.80	1378.20	1376.65	1379.69	3.04	.00221	.00193	2.84	5.90	0.925	.0160
900	1	16.70	16.67	16.63	16.71	0.083	.0050	.00130	2.91	7.76		.0103
	2	103.20	103.10	103.30	0.227	0.022	.00152					
	3	288.50	288.23	288.74	0.516	0.00179	.00135	.00120				
	4	563.00	562.52	563.51	0.983	0.00175	.00144					
	5	931.80	931.10	932.49	1.39	0.00149	.00130					
	6	1393.10	1391.40	1394.62	3.20	0.00204						

TABLE 9

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING 1129

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1700	2	92.32										
	3	257.90	241.10	238.44	242.87	4.43	.0184	.0122				
	4	507.50	509.10	506.82	514.46	7.64	.0150	.0097			6.01	
	5	841.50										
	6	1260.40										
1650	2	93.00	92.75	91.94	93.22	1.29	.01386	.00536	2.20	1.55	3.18	.2050
	3	260.40	259.80	258.73	260.47	1.74	.01305	.00905	2.27	1.65	5.55	.3370
	4	511.80	511.80	509.26	514.69	5.44	.01063	.00663	2.28	1.95	4.11	.2120
	5	849.00	848.80	842.96	852.59	9.63	.0113	.0085	2.30	1.92	5.31	.2760
	6	1271.00	1271.60	1264.86	1277.14	12.30	.00965	.00735	2.31	2.02	4.63	.2290
1600	2	93.75	93.64	92.43	94.17	1.74	.1086	.0129	2.24	1.82	6.61	.3630
	3	262.80	262.71	259.80	263.92	4.12	.0157	.0076	2.32	1.92	8.11	.4220
	4	516.00	517.30	514.77	520.17	5.38	.0104	.0100	2.32	2.29	4.83	.2110
	5	856.00	857.10	850.92	861.10	10.20	.0119	.0100	2.34	2.15	6.38	.2970
	6											
1575	2	94.10	94.66	94.01	96.39	2.37	.0251	.0185	2.25	2.64	11.50	.4360
	3	263.90	264.50	262.41	265.55	3.14	.0119	.00846	2.34	2.27	5.41	.2380
	4	518.20	520.90	518.56	523.30	4.75	.00912	.00679	2.34	2.65	4.39	.1660
	5	859.50	864.30	860.44	868.28	7.84	.00908	.0075	2.36	2.72	4.89	.1800
	6	1286.70	1294.70	1289.30	1299.90	10.60	.00816	.00676	2.37	2.82	4.40	.1580
1525	2	94.85	98.71	96.91	100.51	3.60	.0365	.0320	2.29	7.23	22.60	.3130
	3	266.00	267.10	265.75	268.33	2.58	.00966	.00746	2.37	2.55	4.87	.1910
	4	522.40	525.30	522.93	527.62	4.69	.00892	.00724	2.38	2.74	4.76	.1740
	5	866.30	871.40	867.53	874.97	7.44	.0085	.00735	2.39	2.80	4.87	.1740
	6	1296.70	1305.50	1300.70	1310.10	9.40	.00718	.00611	2.41	2.94	4.08	.1390
1450	2	95.90	96.82	96.56	97.13	0.57	.0115	.00872	2.34	3.22	5.71	.1780
	3	269.10	271.40	270.25	272.45	2.20	.00811	.0068	2.43	3.20	4.61	.1440
	4	528.50	533.30	531.49	535.19	3.70	.00693	.0058	2.44	3.28	3.95	.1200
	5	876.30	884.40	881.76	886.92	5.20	.00584	.00507	2.45	3.32	3.48	.1050
	6	1311.50	1324.00	1320.66	1327.67	7.00	.0053	.00457	2.46	3.37	3.15	.0930
1400	2	96.60	97.83	97.48	98.59	1.10	.0113	.0092	2.38	3.68	6.18	.1680
	3	271.10	273.90	272.73	274.66	1.93	.00703	.00602	2.46	3.49	4.16	.1190
	4	532.40	538.30	536.97	539.90	2.93	.00543	.00449	2.47	3.60	3.12	.0870
	5	882.80	892.30	890.31	894.45	4.14	.00464	.00401	2.49	3.58	2.80	.0780
	6	1321.50	1335.60	1332.98	1338.51	5.53	.00414	.00354	2.50	3.59	2.49	.0690
1350	2	97.30	98.54	98.21	98.91	0.70	.0071	.0053	2.41	3.73	3.61	.0970
	3	273.10	276.50	275.79	277.18	1.40	.00506	.00423	2.50	3.84	3.00	.0780
	4	536.30	542.90	541.86	544.07	2.21	.00407	.00317	2.51	3.83	2.24	.0590
	5	889.00	899.80	898.31	901.47	3.16	.00351	.00298	2.52	3.83	2.72	.0550
	6	1331.00	1346.40	1344.60	1348.60	4.00	.00296	.00246	2.54	3.77	1.76	.0470

TABLE 9 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M29

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1300	2	97.30	98.54	98.21	98.91	0.70	.0071	.0053	2.41	3.73	3.61	.0970
	3	275.00	278.60	277.99	279.13	1.14	.00409	.00339	2.54	3.98	2.43	.0610
	4	540.00	547.10	546.27	547.92	1.65	.00301	.0022	2.54	4.00	1.58	.0400
	5	895.50	906.50	905.22	907.69	2.46	.00272	.0022	2.56	3.90	1.59	.0410
	6	1340.00	1356.10	1354.60	1357.80	3.10	.00231	.00186	2.57	3.88	1.35	.0350
1200	2	99.30	100.97	100.83	101.14	0.31	.00307	.00172	2.51	4.46	1.24	.0280
	3	278.90	283.20	282.91	283.45	0.54	.0019	.00132	2.61	4.44	0.982	.0220
	4	547.50	555.60	555.12	555.96	0.83	.0015	.00084	2.61	4.35	6.25	.0140
	5	908.00	920.10	919.46	920.73	1.27	.0014	.0010	2.63	4.16	7.45	.0180
	6	1359.00	1376.50	1375.70	1377.22	1.50	.0011	.00069	2.64	4.12	5.16	.0120
1100	2	100.60	102.30	102.23	102.42	0.19	.00187	.00067	2.58	4.59	4.94	.0110
	3	282.60	287.20	287.08	287.37	0.29	.0010	.00048	2.68	4.68	3.68	.0078
	4	555.00	563.40	563.22	563.63	0.41	.00073	.00008	2.69	4.52	0.0612	.0014
	5	920.00	933.18	932.84	933.62	0.78	.00084	.00044	2.70	4.43	0.338	.0076
	6	1377.00	1395.50	1349.09	1396.00	0.92	.00066	.00028	2.72	4.32	0.215	.0050

TABLE 10

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M49

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1600	2	94.03	92.09	91.67	92.49	0.82	.0089	.0030	2.29	0.546	0.742	.1360
	3	263.12	257.80	256.84	258.66	1.81	.0070	.0032	2.37	0.585	0.818	.1400
	4	516.69	507.20	505.48	509.16	3.68	.0072	.0046	2.37	0.684	1.18	.1720
	5	857.03	841.60	838.93	844.81	5.88	.0070	.0050	2.39	0.708	1.30	.1840
	6	1282.30	1262.00	1257.55	1266.46	8.92	.0071	.0056	2.40	0.827	1.46	.1770
1500	2	95.68	93.80	93.42	94.15	0.73	.0078	.0042	2.37	0.617	1.08	.1750
	3	267.44	262.47	261.73	263.40	1.68	.0064	.0044	2.45	0.693	1.17	.1690
	4	524.80	517.00	514.64	518.86	4.22	.0082	.0070	2.45	0.896	1.88	.2100
	5	870.50	856.50	850.77	860.96	10.18	.0119	.0108	2.47	0.835	2.91	.3490
	6	1303.20										
1450	2	96.40	94.67	94.30	94.98	0.67	.0071	.0043	2.41	0.717	1.13	.1570
	3	269.60	264.80	263.39	265.93	2.54	.0096	.0082	2.49	0.747	2.22	.2970
	4	529.00	522.40	519.00	525.35	6.35	.0122	.0113	2.49	1.04	3.11	.2980
	5	877.50	865.60	859.07	872.14	13.07	.0151	.0142	2.51	0.99	3.92	.3960
	6	1313.70										
1400	2	97.12	96.03	95.61	96.47	0.86	.0089	.0071	2.45	1.09	1.93	.1760
	3	271.64	267.80	265.91	269.50	3.59	.0134	.0125	2.52	0.964	3.47	.3600
	4	533.10	528.50	523.56	532.54	8.98	.0170	.0162	2.53	1.28	4.58	.3580
	5	884.10	875.90	863.70	887.71	24.00	.0274	.0268	2.54	1.25	7.60	.6090
	6											
1350	2	97.80	97.05	06.43	97.71	1.28	.0132	.0114	2.48	1.31	3.17	.2420
	3	273.60	271.20	268.66	273.73	5.46	.0201	.0192	2.56	1.29	5.49	.4260
	4	536.90	535.70	529.27	541.36	12.10	.0226	.0220	2.56	1.67	6.42	.3850
	5	890.60	890.30	879.89	900.01	20.10	.0226	.0218	2.58	1.79	6.45	.3600
	6	1333.20	1332.60	1313.54	1353.73	40.20	.0302	.0297	2.60	1.79	8.83	.4920
1300	2	98.52	98.34	97.36	99.30	1.94	.0198	.0183	2.52	1.66	5.26	.3160
	3	275.63	275.20	271.28	277.69	6.41	.0233	.0225	2.60	1.73	6.67	.3860
	4	540.90	545.10	538.74	550.99	12.26	.0225	.0220	2.60	2.29	6.71	.2930
	5	897.00	905.10	888.81	914.95	26.15	.0289	.0282				
	6	1342.60										
1275	2	98.89	98.60	97.43	99.74	2.31	.0235	.0221	2.54	1.61	6.37	.3960
	3	276.60	276.60	272.87	279.55	6.68	.0242	.0234	2.62	1.84	7.02	.3820
	4	542.70	549.80	543.89	555.43	11.54	.0210	.0205	2.62	2.63	6.40	.2430
	5	900.20	918.20	901.31	926.35	25.05	.0273	.0266	2.64	3.08	8.53	.2770
	6	1347.20	1375.10	1361.66	1391.98	30.30	.0221	.0216	2.65	3.15	6.98	.2220
1225	2	99.59	100.32	99.06	101.59	2.53	.0252	.0241	2.57	2.24	7.27	.3240
	3											
	4	546.60	557.60	553.40	561.50	8.10	.0145	.0141	2.66	3.11	4.56	.1460
	5	906.70	728.16	921.32	934.14	12.80	.0138	.0131	2.68	3.36	4.31	.1280
	6	1356.50	1392.20	1384.85	1403.31	18.50	.0133	.0129	2.69	3.55	4.30	.1210

TABLE 10 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M49

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1175	2	100.30	102.16	101.18	103.20	2.02	.0198	.0188	2.61	2.96	5.94	.2010
	3	280.50	287.60	285.70	289.70	3.98	.0138	.0132	2.69	3.49	4.39	.1260
	4	550.40	564.30	561.80	566.70	4.90	.0087	.0083	2.69	3.49	2.76	.0790
	5	912.90	939.60	935.37	943.13	7.76	.0083	.0076	2.71	3.78	2.58	.0680
	6	1365.80	1406.70	1402.13	1411.83	9.70	.0069	.0073	2.72	3.84	2.49	.0650
1125	2	101.00	103.64	103.06	104.21	1.15	.01114	.0101	2.65	3.49	3.31	.0950
	3	282.45	290.90	289.84	292.00	2.17	.00745	.00682	2.73	3.84	2.33	.0610
	4	554.20	269.96	568.57	571.30	2.73	.00478	.00437	2.73	3.75	1.49	.0400
	5	919.00	948.70	946.43	950.93	4.50	.00474	.00407	2.75	4.03	1.41	.0350
	6	1375.50	1419.50	1416.80	1422.50	5.64	.00398	.00354	2.76	4.03	1.23	.0306
1050	2	101.95	105.04	104.78	105.28	0.50	.00479	.0047	2.70	3.82	1.59	.0420
	3	285.20	294.60	294.12	295.09	0.97	.0033	.0027	2.78	4.12	0.949	.0230
	4	559.50	576.50	575.80	577.20	1.40	.0024	.0020	2.78	3.95	6.98	.0177
	5	927.60	959.80	958.59	960.89	2.30	.0024	.0017	2.80	4.27	6.05	.0142
	6	1388.50	1435.10	1433.70	1436.80	3.09	.0022	.0017	2.82	4.22	6.06	.0144

TABLE 11

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M32

TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
1650	3	240.00	235.30	233.92	236.71	2.79	.0119	.0064	2.33	0.553	1.76	.3180
	4	471.00	463.90	461.23	466.53	5.29	.0114	.0075	2.33	0.808	2.09	.2590
	5	781.50	768.80	761.09	774.83	13.70			2.35	0.747	3.92	.5250
	6	1169.50	1152.10	1139.86	1160.50	20.60	.0179	.0157	2.36	0.830	4.44	.5350
1600	2	86.75	85.26	84.89	86.06	1.17	.0137		2.31	0.682		
	3	242.10	238.30	236.71	239.93	3.22	.0135	.0095	2.37	0.785	2.69	.3420
	4	475.00	468.80	466.09	472.12	6.03	.0129	.0102	2.37	0.939	2.91	.3100
	5	788.00	778.60	767.75	785.30	17.50			2.39	1.01	5.19	.5140
	6	1179.00	1166.90	1150.28	1177.30	27.00	.02315	.0216	2.40	1.13	6.29	.5650
1550	2	87.55	86.34	85.79	86.58	1.19	.0138	.0058	2.35	8.86	1.64	.1850
	3	244.10	240.90	238.87	242.78	3.91	.0162	.0136	2.41	9.50	3.94	.4150
	4	479.00	473.60	468.45	477.90	9.45	.01995	.0181	2.41	1.06	5.28	.4990
	5	794.50	785.90	773.46	796.43	22.98		.0204	2.43	1.09	6.00	.5490
	6	1188.50	1185.50	1170.60	1197.75	27.16	.0229	.0219	2.44	1.60	6.63	.4150
1500	2	88.30	86.98	86.36	87.73	1.37	.0158	.0104	2.39	0.836	2.98	.3560
	3	246.20	244.50	242.09	246.83	1.74	.0194	.0177	2.45	1.34	5.32	.3970
	4	483.00	479.90	476.44	483.44	7.00	.0218	.0205	2.45	1.37	6.17	.4500
	5	800.50	798.00	784.50	809.52	25.00		.0240	2.46	1.58	7.33	.4650
	6	1198.00	1200.90	1186.10	1214.77	28.70	.0239	.0232	2.48	1.93	7.24	.3750
1450	2	89.00	88.71	87.99	89.67	1.68	.0187	.0152	2.43	1.55	4.58	.2960
	3	248.20	247.70	244.95	250.43	5.48	.0221	.0208	2.49	1.66	6.44	.3870
	4	486.70	487.90	480.33	492.66	12.33	.0253	.0243	2.49	1.94	7.63	.3930
	5	806.50	812.90	799.76	820.95	21.19	.0261	.0242	2.50	2.28	7.76	.3380
	6	1207.00	1218.50	1201.49	1229.71	28.20	.0232	.0226	2.31	2.41	7.32	.3030
1400	2	89.70	89.28	88.31	90.41	2.10	.0235	.0207	2.47	1.48	6.30	.4250
	3	250.10	251.70	248.89	254.51	5.61	.0223	.0213	2.52	2.22	6.87	.3090
	4	490.60	495.70	490.27	500.05	9.78	.0197	.0190	2.53	2.48	6.20	.2500
	5	812.50	824.90	815.53	831.88	16.35	.0198	.0183	2.54	2.81	6.09	.2170
	6	1216.00	1236.90	1225.19	1246.42	21.10	.0172	.0167	2.55	2.95	5.61	.1900
1350	2	90.40	90.46	89.49	91.48	2.00	.0221	.0200	2.50	1.84	6.28	.3410
	3	252.10	254.90	252.50	257.21	4.72	.0185	.0177	2.57	2.57	5.88	.2290
	4	494.50	501.70	497.78	505.36	7.60	.0151	.0145	2.57	2.80	4.87	.1740
	5	818.50	835.00	828.23	840.41	12.20	.0146	.0140	2.57	3.18	4.79	.1510
	6	1225.00	1251.30	1243.20	1258.20	15.00	.0120	.0116	2.59	3.28	4.01	.1220
1300	2	91.00	92.07	91.21	92.90	1.69	.0184	.0167	2.54	2.58	5.50	.2130
	3	253.90	258.40	256.52	260.17	3.65	.0141	.0134	2.60	3.05	4.60	.1510
	4	498.00	507.80	505.08	510.36	5.31	.0105	.0100	2.60	3.18	3.46	.1090
	5	824.50	844.50	840.19	844.50	8.27	.00979	.00922	2.61	3.50	3.24	.0920
	6	1234.00	1264.70	1259.40	1269.52	10.10	.00796	.00761	2.63	3.57	2.70	.0760

TABLE 11 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M32

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-5}$	E_{DI} PSI $\times 10^{-5}$	η_D
1250	2	91.70	92.88	92.23	93.53	1.29	.0139	.0124	2.68	2.69	4.16	.1540
	3	255.80	261.60	259.92	262.41	2.49	.00944	.00878	2.64	3.43	3.11	.0910
	4	501.50	512.80	511.09	514.64	3.60	.0069	.00645	2.64	3.42	2.28	.0670
	5	830.00	852.90	850.05	855.40	5.40	.0063	.0058	2.65	3.78	2.09	.0550
	6	1242.50	1276.50	1272.99	1279.75	6.76	.0053	.0050	2.66	3.79	1.81	.0480
1200	2	92.30	93.86	93.41	94.28	0.86	.0092	.0079	2.61	3.00	2.72	.0900
	3	257.60	263.80	262.95	264.[illegible]	1.60	.00609	.00548	2.68	3.58	1.98	.0550
	4	505.00	517.70	516.53	518.73	2.20	.00424	.00383	2.68	3.66	1.38	.0380
	5	836.00	860.70	858.89	862.29	3.40	.00396	.00344	2.69	3.98	1.26	.0320
	6	1251.00	1287.80	1285.50	1289.70	4.10	.0322	.002[illegible]	2.70	3.99	1.07	.0270
1150	2	92.90	94.90	94.64	95.17	0.53	.00560	.00445	2.64	3.36	1.57	.0470
	3	259.20	266.20	265.69	266.65	0.96	.00362	.00306	2.71	3.84	1.13	.0290
	4	508.50	522.10	521.43	522.77	1.[illegible]4	.00256	.00216	[illegible]	3.82	7.95	.0210
	5	842.00	867.90	866.85	868.96	2.11	.00243	.00192	2.[illegible]	4.12	7.18	.0170
	6	1259.00	1298.40	1296.80	1299.70	2.90	.00211	.00190	2.73	4.18	7.14	.0170
1050	2	94.05	96.47	96.32	96.58	0.26	.00270	.0016	2.71	3.74	5.86	.0160
	3	262.40	270.20	269.93	270.36	0.42	.00157	.00109	2.78	4.13	4.15	.0100
	4	514.50	529.50	529.21	529.86	0.64	.00122	.00084	2.78	4.09	3.19	.0080
	5	852.60	880.10	879.82	880.10	0.77	.00088	.00040	2.79	4.34	1.54	.0035
	6	1275.00	1316.50	1315.80	1317.20	1.40	.00105	.0008	2.[illegible]0	4.38	3.09	.0071
950	2	95.20	97.91									
	3	265.30	273.42									
	4	520.20	535.60									
	5	862.60	890.00									
	6	1290.00	1331.10									

TABLE 12

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M26

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1400	1		13.96									
	2											
	3	254.20	245.70	244.91	246.54	1.63	.00663	.00540	2.52	0.231	1.031	.4460
	4		483.10	480.52	485.55	5.04	.0104	.00805				
	5	806.00							2.54	0.5879	0.1975	.0340
	6		1193.70	1178.40	1204.67	26.30	.0220	.02130				
1300	1	14.63	14.14	14.08	14.21	0.128	.00905	.00880	2.10	0.352	0.421	.0950
	2		91.89	90.63	92.67	2.04	.0222					
	3	258.50	250.20	248.00	253.33	5.30	.0213		2.61	0.294		1.4200
	4		494.95	487.69	504.24	16.50	.0334	.03140				
	5	825.00	781.90	778.88	786.10	7.22	.0092		2.63	0.276	2.08	.2370
	6											
1250	1	14.75	14.35	14.27	14.45	0.182	.0127	.0071	2.14	0.434	1.428	.2650 [1]
	2		91.90	90.62	92.72	2.10	.0228					
	3	260.60	253.90	249.59	259.15	9.55	.0376		2.65	0.486		1.6160 [1]
	4		505.30	493.75	516.32	22.60	.0447	.00428				
	5	846.70	858.80	854.04	863.82	9.78	.0114	.01100	2.67	1.682	3.562	.2120 [1]
	6											
1200	1	14.88	14.55	14.41	14.72	0.312	.0214	.0180	2.17	0.657	3.998	.4610
	2											
	3	262.60	262.20	255.19	270.25	15.10	.0575	.0570	2.20	1.430	1.279	.7240
	4		556.80	540.72	563.41	22.70	.0408	.03890				
	5	878.00							2.712	3.059	4.472	.1460
	6											
1175	1	14.94	15.05	14.83	15.27	0.444	.0295		2.19	0.852		.5250
	2											
	3	263.60	266.50	259.78	275.32	15.50	.0583	.0570	2.71	2.310	1.337	.5800
	4		564.70	560.10	567.67	7.57	.0263					
	5	891.00	835.00	829.05	842.96	13.91	.0167	.01630	2.73	3.644	4.654	.1280
	6		1332.40	1352.80	1393.50	40.70	.0306	.03020				[2]
1150	1	15.00	14.83	14.54	15.15	0.605	.0408	.0360	2.21	1.120	7.917	.5690
	2		92.96	90.72	93.48	3.27	.0351					
	3	264.50	271.02	264.50	278.72	14.20	.0524	.0490	2.73	2.84	11.944	.4210
	4		540.50	534.93	551.02	16.09	.0581	.05600				
	5	902.00	833.70	827.54	844.10	16.56	.0199	.01960	2.75	4.127	4.60	.1110
	6		1345.55	1340.10	1351.90	11.78	.0171	.01670				
1125	1	15.06	14.96	14.54	15.36	0.808	.0540	.0510	2.23	1.47	11.614	.6370
	2											
	3	265.50	275.07	267.20	281.14	11.94	.0434	.0380	2.75	3.44	9.658	.2810
	4		565.30	558.97	568.30	9.34	.0322					
	5	911.10	911.70	907.80	915.60	7.80	.0168	.01650	2.769	4.502	4.424	.0980
	6		1366.30									

TABLE 12 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M26

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1100	1	15.11	15.34	14.74	15.80	1.05	.0685		2.24	1.95		.6290
	2		102.24	101.91	102.76	0.85	.00833					
	3	266.40	277.90	273.42	282.53	9.11	.0328	.0285	2.77	3.83	7.448	.1940
	4		546.90	544.84	548.61	3.77	.00689	.00490				
	5	918.00	923.20	918.30	927.70	8.43	.00913	.08810	2.79	4.737	4.011	.0850
	6		1369.90	1363.90	1377.22	13.30	.00974					
1075	1	15.16	15.53	14.99	16.04	1.05	.0678	.0640	2.26	2.50	15.932	.5300
	2		102.75	102.26	103.15	0.89	.00863					
	3	267.30	280.34	277.00	283.95	6.95	.0248	.0215	2.79	4.21	5.770	.1370
	4		547.70	546.00	549.45	3.42	.00624					
	5	923.50	922.90	920.30	926.10	5.80	.0122		2.808	4.938	3.566	.0720
	6		1374.50	1382.20	1369.20	12.90	.0094					
1050	1	15.21	15.87	15.86	16.30	0.939	.0592		2.27	3.17		.3743
	2											
	3	268.20	282.70	280.19	285.31	5.12	.0181	.0162	2.81	4.52	4.446	.0983
	4											
	5	928.00	925.30	921.32	930.58	9.30	.0100		2.827	5.052	3.038	.0600
	6		1382.00	1375.70	1389.50	13.76	.00996	.00960				
1000	1	15.31	16.31	15.99	16.57	0.58	.0356	.0315	2.30	4.24	8.987	.1708
	2											
	3	269.90	286.20	284.68	287.67	3.00	.0104	.0096	2.84	4.99	2.728	.0546
	4		562.20	560.10	565.20	5.13	.00913	.00673				
	5	936.00	933.50	928.94	937.03	8.10	.00867	.00840	2.865	5.232	2.171	.0410
	6		1396.10	1391.20	1400.95	9.75	.0070					
950	1	15.40	16.57	16.42	16.71	0.29	.0176	.0140	2.33	4.62	4.127	.0720
	2		103.10	102.70	103.56	0.86	.00836					
	3	271.50	289.20	288.24	290.09	1.85	.0064	.0060	2.88	5.31	1.749	.0329
	4		566.80	565.26	568.47	3.21	.00567					
	5	942.50	942.77	939.67	945.09	5.42	.00575		2.899	5.354	1.616	.0300
	6		1409.00	1405.48	1412.03	6.50	.00465	.00430				
850	1	15.68						.0010	2.41	4.61	0.302	.00529
	2											
	3	274.60						.0032	2.94	5.62	0.963	.0171
	4											
	5	955.00							2.964	5.602	1.028	.0180
	6											
800	1											
	2		105.80	105.60	105.95	0.35	.00331	.00257				
	3		295.80	295.45	296.37	0.42	.00311					
	4		579.20	578.03	580.28	2.25	.00388	.00170				
	5		962.90	961.35	961.41	3.06	.00318	.00290				
	6		1438.20	1436.37	1440.51	4.14	.00288					

TABLE 12 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M26

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
600	1		17.36	17.33	17.42	0.083	.00478					
	2		107.90	107.76	108.07	0.309	.00286					
	3		301.80	301.50	302.25	0.75	.00248					
	4		592.80	591.96	593.61	1.65	.00279					
	5		982.90	981.84	984.16	2.32	.00236	.00210				
	6		1468.00	1466.47	1469.55	3.08	.0021	.00180				

(1) $F_C \to \eta_C$ @ 1255°

(2) APPROXIMATE

TABLE 13

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M12

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1600	1	14.06	13.76	13.66	13.87	0.208	.0151	.00210				
	2	87.56	87.44	87.03	88.21	1.17	.0134	.00680				
	3	245.50	245.30	243.72	246.62	2.90	.0118	.00600				
	4	482.70	489.30	486.85	492.13	5.30	.0108	.00610				
	5	800.80	800.80	789.20	806.20	17.00	.0212	.01550				
	6	1199.00	1197.70	1179.50	1208.50	28.90	.0242	.02100				
1500	1	14.27	14.01	13.89	14.12	0.23	.0162	.00820	2.38	1.28	1.21	.2060
	2		89.01	88.51	89.92	1.31	.0147	.00660				
	3	250.30	250.40	247.98	252.39	4.42	.0176	.01490	2.39	1.87	5.26	.2820
	4	491.30	490.20	486.85	493.00	6.14	.0125	.01070	2.39	2.78	5.30	.1910
	5	815.80	786.20	781.98	794.66	12.68	.0161	.01330	2.41	2.54	5.38	.2110
	6	1222.00	1248.60	1244.86	1252.50	7.61	.0061	.00490	2.43	2.54	2.03	.0800
1450	1	14.18	14.19	14.08	14.30	0.22	.0158	.00111				
	2	90.17	90.00	91.10	89.33	1.76	.0196	.01210				
	3	252.19	253.10	250.47	255.70	5.23	.0207	.01870				
	4		499.50	499.58	504.85	5.47	.0107	.00936				
	5	823.30	825.80	816.59	832.57	16.00	.0193	.01720				
	6	1232.30	1243.50	1239.77	1251.78	12.00	.00966	.00886				
1400	1	14.53	14.51	14.35	14.62	0.271	.0187	.00650	2.47	1.68	2.66	.1590
	2		89.70	92.65	89.05	3.61	.0402					
	3	255.00	255.40	252.26	258.72	6.46	.0253	.02450	2.47	2.89	10.50	.3630
	4	500.00	503.90	496.23	510.57	14.30	.0285	.02000	2.47	3.60	8.80	.2450
	5	830.60	835.40	825.46	842.39	16.93	.0203	.01870	2.41	3.54	5.75	.1630
	6	1270.00	1241.30	1235.94	1266.87	30.90	.0249	.02440	2.53	3.66	6.71	.1830
1350	1	14.63	14.51	14.35	14.66	0.309	.0213	.01700	2.52	1.71	4.76	.2780
	2		92.89	91.57	93.61	2.04	.0220	.01860				
	3	262.00	260.10	263.94	256.61	7.32	.0280	.02690	2.52	3.48	12.00	.346
	4	517.40	513.40	509.53	517.09	7.56	.0287	.0279	2.52	4.22	8.57	.2030
	5	858.20	848.00	842.89	855.14	12.30	.0145	.01320	2.54	4.08	5.50	.1350
	6	1288.00	1286.80	1270.00	1298.50	28.50	.0220	.02160	2.57	4.26	9.26	.2180
1300	1	14.80	14.68	14.48	14.88	0.405	.0276	.01800	2.56	1.98	7.72	.3910
	2		93.24	92.66	93.95	1.29	.0138					
	3	266.00	264.20	260.88	267.49	6.61	.0250	.02480	2.56	4.14	11.45	.2770
	4	508.30	520.00	525.57	515.56	10.00	.0193	.01500	2.56	4.88	7.07	.1450
	5	846.30	863.04	859.36	869.34	9.97	.0116	.01060	2.59	3.54	5.75	.1630
	6	1305.00	1295.80	1285.35	1306.51	21.16	.0163	.01600	2.61	4.77	7.65	.1600
1250	1	15.04	14.94	14.70	15.15	0.45	.0301	.02350	2.61	2.66	10.49	.3940
	2	93.44	93.62	93.16	94.76	1.60	.0171	.02350				
	3	269.90	268.60	265.67	271.08	5.42	.0202	.01850	2.61	4.76	8.85	.1860
	4	531.50	527.30	530.36	523.40	6.97	.0132	.01100	2.60	5.35	5.35	.1010
	5	880.40	875.40	880.28	862.37	18.00	.0205	.01960	2.63	5.06	3.45	.0680
	6	1320.00	1312.60	1304.97	1320.04	15.10	.0115	.01130	3.09	3.25	3.46	.1533

TABLE 13 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M12

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M psi $\times 10^{-7}$	E_{DR} psi $\times 10^{-6}$	E_{DI} psi $\times 10^{-6}$	η_D
1200	1	15.29	15.22	15.00	15.44	0.442	.0290	.02400	2.64	3.54	11.20	.3160
	2		93.62	93.08	94.83	1.75						
	3	273.40	271.70	270.04	273.37	3.33	.0123	.01150	2.65	5.31	5.68	.1070
	4	516.60	535.60	533.73	538.24	4.50	.00842	.00750	2.64	5.76	3.75	.0650
	5	859.00	885.20	881.13	888.34	7.20	.00814	.00736	2.67	5.44	2.45	.0450
	6	1286.00	1325.70	1323.60	1328.02	4.40	.0065	.00630	2.70	5.55	2.36	.0430
1150	1	15.16	15.45	15.28	15.61	0.33	.0214	.01770	2.69	4.14	8.53	.2060
	2	95.26	98.00	98.43	97.12	1.31	.0134					
	3	266.10	274.90	273.92	275.91	2.00	.00724	.00640	2.69	5.77	3.25	.0560
	4	520.50	539.80	538.16	541.65	3.50	.00648	.00500	2.68	6.12	2.56	.0420
	5	865.80	894.60	892.54	896.46	3.90	.00429	.00330	2.72	5.74	1.94	.0340
	6	1296.00	1338.50	1336.00	1341.74	5.70	.00428	.00290	2.74	5.84	1.49	.0260
1100	1	15.27	15.71	15.59	15.81	0.21	.0340	.01060	2.73	4.81	5.28	.1100
	2		99.03	98.68	99.31	0.64	.00643					
	3	268.00	277.20	276.64	277.81	1.20	.00423	.00350		6.09	1.81	.0300
	4	524.50	544.20	543.18	545.29	2.10	.00386	.00340	2.72	6.30	1.78	.0280
	5	872.20	901.55	900.09	902.69	2.60	.00288	.00223	2.76	5.96	1.14	.0190
	6	1305.20	1349.20	1347.16	1351.17	4.00	.00297	.00282	2.78	6.03	1.15	.0190
1000	1	15.46	16.02	15.98	16.08	0.095	.00593	.00470	2.80	5.67	2.46	.0430
	2	97.28	100.50	100.41	100.67	0.258	.00256					
	3	271.40	281.10	280.89	281.40	0.52	.00184	.00140	2.80	6.27	0.745	.0120
	4	531.50	551.40	550.87	552.06	1.19	.00215	.00178	2.80	6.49	0.952	.0150
	5	883.50	913.30	912.66	914.24	1.59	.00174	.00111	2.83	6.19	0.510	.0190
	6	1322.50	1366.70	1365.37	1367.80	2.43	.00178	.00167	2.85	6.18	0.805	.0130
900	1	15.64	16.21	16.18	16.24	0.068	.00422	.0029	2.86	5.83	0.155	.0270
	2	97.86	101.70	101.59	101.77	0.177	.00174					
	3	274.40	284.40	284.19	284.55	0.364	.00128	.00085	2.86	6.36	0.462	.0070
	4	537.60	557.60	557.13	558.16	1.03	.00184	.00120	2.86	6.41	0.652	.0100
	5	893.20	923.90	923.28	924.56	1.28	.00139	.00054	2.89	6.21	0.270	.0040
	6	1337.30	1382.30	1381.43	1383.20	1.78	.00129	.00121	2.91	2.91	0.704	.0011

TABLE 14

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M21

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M psi $\times 10^{-7}$	E_{DR} psi $\times 10^{-6}$	E_{DI} psi $\times 10^{-5}$	η_D
1600	2	93.72	94.06	93.07	95.70	2.64	.0280	.02200	2.27	1.49	3.36	.2340
	3	262.80	265.70	264.49	272.08	10.60	.0400	.01412	2.35	1.84	3.85	.2090
	4	515.80	523.80	516.72	532.00	15.30	.0292	.02660	2.36	1.96	4.71	.2400
	5	856.00	879.20	866.78	889.44	22.70	.0258	.02380	2.37	2.13	4.09	.1920
	6	1281.30	1311.00	1296.18	1324.50	28.30	.0216	.02010	2.39	2.26	3.67	.1620
1550	2	94.51	95.43	94.35	96.49	2.14	.0224	.01780	2.31	1.76	3.59	.2050
	3		269.50	266.16	272.50	6.40	.0237	.02100				
	4		532.10	526.04	538.04	12.00	.0226	.02080				
	5		884.90	877.19	892.22	15.03	.0170	.01560				
	6		1327.80	1316.66	1336.90	20.20	.0153	.01480				
1500	2	95.31	96.83	95.95	98.08	2.13	.0220	.08140	2.34	2.00	3.22	.1610
	3	267.10	272.59	268.93	274.95	6.02	.0221	.02010	2.43	2.26	3.16	.1400
	4	524.30	538.90	534.22	543.32	9.10	.0169	.01570	2.44	2.50	2.98	.1190
	5	869.70	894.90	887.86	900.66	12.80	.0143	.01320	2.45	2.54	2.43	.0958
	6	1301.30	1342.20	1333.90	1349.50	15.63	.0116	.10800	2.46	2.64	1.99	.0757
1450	2	96.10	98.21	97.47	99.21	1.74	.0177	.01490	2.38	2.21	2.70	.1220
	3	269.20	276.00	272.94	277.65	4.71	.0171	.01570	2.47	2.43	2.44	.1010
	4	528.40	544.51	541.18	547.71	6.52	.0120	.01110	2.48	2.64	2.16	.0817
	5		903.80	899.04	907.50	8.49	.0094	.00850				
	6		1354.30	1348.80	1359.43	10.60	.0079	.00730				
1400	2	96.88	99.35	98.78	100.07	1.29	.0129	.01020	2.42	2.38	2.01	.0843
	3	271.30	279.10	277.59	280.35	2.76	.0099	.00880	2.50	2.58	1.70	.0660
	4	532.50	550.10	547.77	552.21	4.45	.0081	.00740	2.51	2.74	1.51	.0549
	5	883.20	912.20	908.51	915.58	7.07	.0078	.00700	2.53	2.75	1.30	.0471
	6	1321.10	1366.30	1362.53	1370.05	7.52	.0055	.00500	2.54	2.80	1.04	.0369
1350	2	97.63	100.19	99.71	100.68	0.97	.0097	.00790	2.46	2.49	1.47	.0592
	3	273.40	281.70	280.69	282.65	1.97	.0070	.00610	2.54	2.69	1.20	.0446
	4	536.50	554.66	553.07	556.24	3.17	.0057	.00510	2.55	2.83	1.01	.0356
	5		920.00	917.77	922.51	4.74	.0052	.00450				
	6		1376.50	1374.00	1380.07	6.07	.0044	.00390				
1300	2	98.38	101.25	100.91	101.60	0.69	.0068	.00530	2.50	2.59	1.07	.0415
	3	275.45	284.20	283.43	284.84	1.41	.0050	.00420	2.57	2.78	0.834	.0300
	4	540.50	559.22	558.38	560.41	2.03	.0036	.00310	2.58	2.90	0.677	.0233
	5	896.20	927.30	925.55	929.02	3.47	.0037	.00300	2.60	2.93	0.682	.0232
	6	1340.50	1387.30	1385.43	1389.66	4.24	.0031	.00270	2.61	2.94	0.571	.0194
1250	2	99.07							2.53	2.69	7.96	.0296
	3	277.45							2.62	2.86	3.93	.0137
	4	544.40							2.62	2.97	5.01	.0169
	5	902.50							2.64	3.00	4.94	.0165
	6	1350.00							2.65	3.01	4.34	.0144
1200	2	99.72	102.93	102.71	103.13	0.41	.0040	.00300	2.57	2.78	6.07	.0218
	3	279.45	288.80	288.38	289.22	0.83	.0029	.00220	2.66	2.93	4.63	.0158
	4	548.30	568.10	567.31	568.80	1.48	.0026	.00220	2.66	3.04	4.45	.0146
	5	941.70	941.50	940.38	942.77	2.39	.00254	.00190				
	6		1408.60	1407.26	1410.04	2.78	.00197	.00160				

TABLE 14 (Continued)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M21

Experimental Measurements									Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-4}$	E_{DI} PSI $\times 10^{-8}$	η_D
1400	2	96.45	99.42	99.00	99.91	0.91	.0092	.0070				
	3	270.30	279.40	278.43	280.42	1.99	.0071	.0060				
	4	530.75	550.00	548.16	551.82	3.66	.0067	.0060	2.51	4.61	2.44	.0530
	5	879.40	910.80	907.77	913.08	5.30	.0058	.0050				
	6	1317.00	1362.20	1358.51	1365.37	6.86	.0050	.0044				
1350	2	97.20	97.90	97.77	98.01	0.24	.0024	.00065	2.45	2.35	2.37	.0101
	3	272.10	273.90	273.69	274.10	0.41	.0015	.0006				
	4	530.80	537.50	537.29	537.87	0.58	.0011	.00049				
	5	886.40	891.20	890.71	891.70	0.79	.0011	.00031				
	6	1326.50	1333.50	1332.80	1334.04	1.24	.00093	.00043	2.57	2.32	3.54	.0153
1300	2	97.94	98.65	98.54	98.75	0.204	.00207	.00067				
	3	274.50	276.00	275.82	276.14	0.32	.00116	.00037				
	4	538.80	541.60	541.39	541.89	0.50	.00092	.00036	2.58	4.91	1.52	.0310
	5	893.20	897.80	897.50	898.15	0.64	.00072					
	6	1336.80	1343.40	1342.73	1343.40	0.99	.00074	.00024				

TABLE 15

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M35

		Experimental Measurements							Material Properties				
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D	
1600	2	83.97	84.85	83.28	86.10	2.82	.0332	.0262					(1)
	3	235.00	239.10	235.63	242.49	6.90	.0287	.0245					(1)
	4	461.40	468.70	460.96	476.53	15.60	.0332	.0305					(1)
	5	764.90	772.90	764.53	779.67	15.10	.0195						(1)
	6	1134.90	1177.30	1159.30	1193.50	34.20	.0291						(1)
1550	2	84.54	83.53	83.15	84.08	0.93	.0111	.00533	2.35	1.01	1.43	.1420	
	3	236.80	233.00	231.79	234.16	2.37	.0102	.0075	2.43	0.764	2.05	.2680	
	4	464.90	455.20	451.16	460.02	8.86	.0195	.0178	2.43	0.545	1.79	.3240	
	5	771.00	758.60	750.98	764.00	13.00	.0172	.0157	2.45	0.816	4.34	.5320	
	6	1153.50	1134.80	1124.50	1144.00	19.60	.0172	.0163	2.46	0.798	4.44	.5560	
1500	2	85.14	83.89	83.49	84.20	0.70	.00838	.00408	2.38	0.870	1.10	.1270	
	3	238.80	234.40	233.40	235.42	2.00	.0086	.0068	2.47	0.690	1.18	.2730	
	4	468.70	461.00	458.23	463.65	5.41	.0118	.0106	2.47	0.804	2.96	.3680	
	5	777.00	764.30	756.70	770.20	13.50	.0176	.0165	2.49	0.814	4.63	.5690	
	6	1162.50	1144.60	1132.00	1156.30	24.30	.0213	.0206	2.50	0.891	5.94	.6670	
1450	2	85.87	84.61	84.22	85.02	0.80	.00948	.00628	2.42	0.885	1.72	.1950	
	3	240.60	236.70	235.18	238.18	3.00	.0127	.0114	2.51	0.828	3.22	.3900	
	4	472.40	466.10	462.02	470.32	8.30	.0178	.0169	2.51	0.996	4.83	.4850	
	5	783.00	773.30	760.23	781.77	21.50	.0279	.0270	2.53	1.06	7.78	.7370	
	6	1171.00	1161.20	1141.70	1177.02	35.30	.0304	.0299	2.54	1.31	8.79	.6700	
1400	2	86.52	85.46	84.89	86.07	1.18	.0139	.0114	2.46	1.04	3.20	.3090	
	3	242.45	239.40	237.08	241.77	4.70	.0196	.0186	2.54	1.05	5.40	.5130	
	4	475.90	472.80	466.70	479.20	12.50	.0264	.0257	2.55	1.41	7.61	.5380	
	5	789.00	786.00	767.81	796.24	28.40	.0362	.0354	2.56	1.59	10.60	.6700	
	6	1180.00	1183.20	1160.80	1204.80	44.10	.0372	.0368	2.57	2.00	11.40	.5680	
1350	2	87.19	86.45	85.49	87.40	1.91	.0221	.0201	2.50	1.27	5.80	.4560	
	3	244.50	243.00	239.56	246.46	6.91	.0284	.0276	2.59	1.46	8.31	.5690	
	4	479.30	481.40	473.89	489.00	15.10	.0314	.0308	2.59	2.10	9.55	.4550	
	5	794.50	799.20	782.04	810.64	28.60	.0358	.0351	2.60	2.21	11.00	.4980	
	6	1188.50	1207.60	1189.50	1235.90	46.50	.0385	.0381	2.61	2.88	12.30	.4280	
1300	2	87.90	87.97	86.57	89.60	3.04	.0345	.0328	2.54	1.85	9.88	.5360	
	3	246.00	247.50	243.67	251.71	8.04	.0325	.0317	2.62	2.24	10.00	.4480	
	4	482.90	490.70	483.75	497.93	14.20	.0289	.0284	2.63	2.88	9.26	.3220	
	5	800.20	819.40	809.91	828.78	18.90	.0230	.0225	2.64	3.40	7.54	.2220	
	6	1197.00	1230.00	1216.70	1251.60	34.90	.0284	.0280	2.65	3.62	9.52	.2620	
1250	2	88.58	89.85	88.30	91.72	3.42	.0380	.0365	2.58	2.71	11.60	.4290	
	3	247.70	252.60	249.20	255.91	6.70	.0265	.0259	2.66	3.13	8.63	.2760	
	4	486.40	498.90	493.63	504.18	10.60	.0212	.0206	2.66	3.55	7.01	.1980	
	5	806.00	829.30	822.17	836.40	14.20	.0172	.0166	2.68	3.78	5.73	.1520	
	6	1205.50	1245.20	1236.71	1256.91	20.21	.0162	.0159	2.69	4.11	5.621	.1370	

TABLE 15 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M35

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-}$[illegible]	E_{DR} PSI $\times 10^{-}$[illegible]	E_{DI} PSI $\times 10^{-}$[illegible]	η_D
1200	2	89.29	92.00	90.73	93.63	2.91	.0316	.0302	2.62	3.79	1.02	.2700
	3	249.60	256.90	254.58	259.11	4.53	.0176	.0170	2.70	3.83	5.92	.1550
	4	489.80	505.70	502.44	508.96	6.50	.0129	.0124	2.70	4.06	4.36	.1080
	5	811.50	840.20	835.28	844.45	9.17	.0109	.0104	2.71	4.17	3.71	.0870
	6	1214.00	1259.00	1253.90	1265.20	11.30	.0090	.00865	2.72	4.47	3.10	.0690
1150	2											
	3	251.30	260.30				.0090		2.73	4.34	3.24	.0747
	4	493.20	511.60				.0068		2.74	4.45	2.46	.0550
	5	817.00	849.30				.0059		2.75	4.63	2.16	.0470
	6	1222.00	1272.30				.0045		2.76	4.76	1.66	.0350
1100	2	90.54	94.69	94.24	95.15	0.897	.0095	.0083	2.69	4.97	3.03	.0610
	3	253.00	262.90	262.17	263.58	1.41	.0054	.0049	2.77	4.63	1.81	.0390
	4	496.40	516.10	515.01	517.09	2.08	.0040	.0036	2.77	4.68	1.33	.0280
	5	822.40	857.00	855.29	858.66	3.38	.0039	.0035	2.79	4.87	1.31	.0270
	6	1230.00	1282.40	1280.41	1284.36	3.95	.0031	.0027	2.80	4.93	1.01	.0210
1050	2											
	3											
	4	499.50	520.00				.0022		2.81	4.83	0.826	.0170
	5											
	6	1238.00	1292.00				.0019		2.83	5.06	0.725	.0140
1000	2	91.73	96.26	96.06	96.40	0.32	.0033	.0022	2.76	5.35	0.833	.0156
	3	255.50	266.90	266.59	267.14	0.55	.0021	.0016	2.83	4.87	0.793	.0163 (2)
	4	501.20	523.60	523.18	524.11	0.93	.0018	.0014	2.83	4.87	0.662	.0140 (2)
	5	830.30	869.30	868.43	870.17	1.74	.0020	.0016	2.84	5.05	0.745	.0150 (2)
	6		1300.60	1299.50	1301.70	2.22	.0017	.0014				

(1) SLIGHT INTERFERENCE WITH BAFFLE.

(2) $E_D \rightarrow \eta_D$ @ 1025 °F

TABLE 16

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M24

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1650	1		236.60	234.59	238.54	3.96	.0167	.0107				
	2		236.60	234.59	238.54	3.96	.0167	.0107	2.36	0.634		.4420
	3		449.30	444.95	454.03	9.08	.02021	.0167	2.36	0.635	2.801	.4423
	5		777.00	764.18	785.79	21.62	.0278	.0244	2.39	1.05	6.458	.6130
	6		1165.60	1133.53	1178.00	44.50	.03815	.0364				
1600	1	13.57										
	2	86.55										
	3	243.10	239.80				.0195	.0108	2.40	0.921	5.231	.5680
	4	477.70										
	5	792.60	789.00	766.05	801.55	35.50	.0450	.0426	2.43	1.46	8.937	.0320
	6	1186.50	1187.00	1157.01	1205.98	48.98	.0413	.0400	2.43	1.74	7.999	.4570
1550	1	14.03	14.88	14.73	15.01	0.274	.0184					(1)
	2	87.57										
	3	245.20	242.66	239.57	244.08	4.51	.0363	.0337	2.44	1.33	8.014	.6040
	4	481.50	453.20	450.53	456.45	5.92	.0131					
	5	798.70	803.00					.0375	2.46	2.03	10.948	.5390
	6	1195.60	1550.00					.0300	2.47	2.47	9.026	.3620
1500	1	14.45	13.97	13.63	14.17	0.54	.0386	.0216				
	2	88.32										
	3	247.20	248.00	242.78	251.66	8.88	.0358	.0340	2.49	1.96	9.922	.5070
	4	485.40										
	5	805.10	819.40	798.72	830.29	31.60	.0385	.0372	2.50	2.72	4.959	.4050
	6	1205.30	1232.50					.0270	2.51	3.13	8.500	.2700
1450	1		14.25	13.96	14.51	0.54	.0379	.0264				
	2		89.77	88.67	91.25	2.58	.0288	.0260				
	3	249.10	252.60	247.61	256.50	8.90	.0352	.0339	2.52	2.61	10.400	.3980
	4		496.00	488.50	503.50	15.00	.0303	.0293				
	5	811.50	832.30	820.20	841.89	21.70	.02604	.0250	2.54	3.37	9.288	.2760
	6	1214.50	1250.90	1237.00	1265.18	28.20	.0225	.0219	2.55	3.66	7.065	.1920
1400	1	15.61	14.83	14.58	15.11	0.54	.0361	.0264				
	2	89.97	91.32	90.06	93.40	3.34	.0366	.0342				
	3	251.23	257.00	252.92	260.55	7.61	.0296	.0286	2.56	3.26	9.118	.2800
	4	493.14	506.10	502.01	509.32	7.30	.0282	.0275				
	5	817.80	843.70	834.24	852.73	18.50	.0219	.0210	2.58	3.88	3.324	.1710
	6	1224.30	1267.70	1257.40	1276.98	19.60	.0155	.0150				
1350	1											
	2											
	3	253.00	261.60	258.83	263.98	5.15	.0197	.0189	2.60	3.86	6.661	.1730
	4		514.70	509.80	517.90	8.07	.0157	.0151				
	5	824.00	856.40	850.92	861.70	10.80	.0126	.0118	2.62	4.35	4.296	.0980
	6	1233.00	1282.20	1275.20	1288.70	13.50	.0105	.0102	2.63	4.38	3.569	.0810

TABLE 16 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M24

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1300	1	15.42										
	2	91.18										
	3	254.80	264.80	263.01	266.53	3.53	.0133	.0126	2.64	4.32	4.339	.1060
	4	500.20	520.40	517.73	523.07	5.33	.0103	.0097				
	5	829.40	865.00	861.18	868.51	7.33	.00847	.0078	2.66	4.64	2.819	.0600
	6	1241.50	1294.70	1289.49	1299.04	9.50	.0074	.00709				
1200	1	15.85										
	2	92.35										
	3	258.60	270.30	269.56	271.05	1.50	.0055	.0050	2.71	4.27	1.653	.0390
	4	507.60	530.20	529.10	531.32	2.22	.0042	.00372				
	5	841.70	880.10	878.35	881.68	3.33	.0378	.00323	2.74	4.94	1.142	.0230
	6	1259.90	1316.30	1314.41	1318.57	4.20	.00316	.00291				
1100	1	15.55										
	2	93.80	98.16	98.08	98.25	0.17	.00338	.00233				
	3	262.29	274.50	274.10	274.82	0.71	.00258	.00209	2.79	5.16	4.259	.0130
	4	514.80	538.00	537.43	538.50	1.07	.00199	.00154				
	5	853.50	892.90	892.06	893.66	1.60	.00179	.00129	2.81	5.16	5.117	.0100
	6	1277.50	1335.10	1334.00	1336.00	1.96	.00147	.00124				
1050	1											
	2											
	3	264.00	276.40				.0011		2.83	5.24	0.416	.0080
	4											
	5	858.70	898.70				.0010		2.85	5.25	0.0362	.0070
	6											
1000	1	15.39										
	2	94.88	99.35	99.25	99.43	0.19	.00189	.00084				
	3	265.40	278.30	278.14	278.47	0.33	.0012	.00072				
	4	520.90	545.20	544.87	545.55	0.68	.00125	.00089				
	5	863.70	904.80	904.32	905.31	0.98	.00109	.00069				
	6	1292.60	1352.80	1352.10	1353.45	1.40	.00101	.00078				

(1) η_{bb} = .02+

TABLE 17

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M11

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1450	2	88.71	86.88	87.18	86.69	0.50	.00574	.0030	2.41	5.83	0.7971	.1320
	3	248.00	242.20	242.96	241.48	1.48	.00613	.00485	2.49	0.452	1.274	.2820
	4		480.10	481.30	478.54	2.76	.0092	.0103				
	5	806.60	789.20	793.90	784.13	9.80	.0124	.0116	2.50	5.40	3.193	.5910
	6	1207.10	1181.61	1190.90	1170.96	19.90	.01688	.0162	2.51	5.78	4.324	.7430
1400	2	89.42	87.54	87.86	87.30	0.56	.0064	.00417	2.45	5.71	1.133	.1920
	3	249.90	244.20	245.34	243.07	2.27	.00928	.00833	2.52	0.49	2.218	.4530
	4		484.60	485.93	482.51	3.42	.0138	.0130	2.54	0.679		
	5	812.60	796.90	804.57	788.33	16.24	.0204	.0198			4.977	.7320
	6	1216.10	1194.20	1206.42	1174.95	31.50	.0264	.0259			6.050	.8000
1350	2	90.12	88.39	88.89	88.04	0.845	.00956	.00746	2.49	0.679	2.065	.2940
	3	251.84	246.85	248.67	245.07	3.60	.0146	.0138	2.56	0.664	3.778	.5690
	4		489.80	493.41	482.37	11.04	.0225	.0218				
	5		806.00	816.70	794.50	22.20	.0275	.0269				
	6	1224.80	1212.00	1221.00	1202.90	18.10	.0291	.0286	2.58	1.20	8.560	.7110
1300	2	90.79	89.27	90.16	88.72	1.44	.0161	.0141	2.53	0.825	3.970	.4160
	3	253.70	249.70	252.72	247.15	5.58	.0223	.0216	2.60	0.905	6.102	.6750
	4											
	5	824.40	820.00	831.81	801.15	30.65	.0374	.0368	2.61	1.44	11.050	.7650
	6	1253.50	1233.20	1253.30	1202.50	50.79	.0412	.0408	2.10	0.906		1.3210
1250	2	91.44	90.68	91.44	90.15	1.29	.0277	.0257	2.56	1.32	7.466	.5500
	3	255.53	253.90	258.40	250.20	8.20	.0323	.0316	2.64	1.47	9.122	.6220
	4											
	5	830.20	836.10	850.56	812.35	38.20	.0457	.0452	2.65	2.28	13.810	.6060
	6	1242.20	1260.20	1286.70	1228.20	58.47	.0464	.0461	2.66	2.73	14.530	.5280
1200	2	92.06	91.85					.0380	2.60	1.68	11.480	.6600
	3	257.30	259.70	264.70	255.08	9.61	.0370	.0363	2.68	2.44	11.300	.4630
	4	505.10	513.35	521.24	515.44	15.80	.0308	.0303	2.68	2.88	9.991	.3430
	5	836.00	854.70	867.83	836.54	31.30	.03601	.0361	2.69	3.29	11.900	.3610
	6	1250.90	1291.00	1317.00	1269.20	47.80	.03703	.0367	2.69	3.91	12.320	.3130
1150	2	92.66	93.82					.0450	2.63	2.60	14.390	.5360
	3	259.00	266.25	270.45	261.63	8.82	.0331	.0320	2.71	3.60	10.970	.3050
	4	507.50	524.30	530.08	516.48	13.61	.02595	.0250	2.71	3.99	8.327	.2080
	5		872.60	881.29	861.40	19.90	.0228	.0222				
	6	1275.00	1312.00	1325.38	1299.55	25.80	.0197	.0193	2.80	5.33	6.688	.1440
1100	2	93.24	96.05					.0410	2.67	3.74		.3620
	3	260.60	270.40	273.69	267.36	6.33	.0234	.0228	2.75	4.35	7.953	.1830
	4		532.70	536.45	528.54	7.91	.0149	.0144				
	5	847.10	885.20	889.44	879.43	10.00	.0113	.0108	2.76	4.85	3.928	.0808
	6	1267.40	1326.60	1333.30	1319.80	13.50	.0102	.0099	2.76	5.01	3.619	.0717

TABLE 17 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M11

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1050	2	93.79	97.94	98.40	97.18	1.21	.02418	.0230	2.70	4.68	8.26117	.1710
	3	262.20	274.56	276.33	272.94	3.39	.0123	.0118	2.78	5.05	4.266	.0844
	4	513.40	538.50	540.77	536.22	4.55	.00845	.00795	2.77	4.78	3.714	.0775 (1)
	5		894.90	898.10	891.50	6.64	.00743	.0069				
	6	1275.00	1339.40	1343.73	1334.94	8.79	.00656	.00627	2.80	5.33	2.210	.0414
1000	2	94.33	99.44	99.84	98.78	1.05	.01061	.0096	2.73	5.34	3.580	.0650
	3	262.93	277.62	278.53	276.67	1.86	.00669	.00619	2.79	5.42	3.176	.0585 (2)
	4	516.40	543.50	544.78	542.18	2.60	.00478	.00428	2.80	5.13	2.085	.0406 (2)
	5	854.90	903.10	905.22	900.98	4.24	.0047	.0043	2.81	5.45	1.894	.0347 (2)
	6		1351.40	1354.32	1348.51	5.81	.0043	.00406				
900	2		101.17	101.33	100.97	0.357	.00353	.00265				
	3		282.00	282.41	281.63	0.78	.00276	.00236				
	4		551.60	552.27	550.90	1.37	.00248	.00192				
	5		916.30	917.43	915.16	2.27	.00247	.00213				
	6		1371.00	1372.57	1369.36	3.21	.00234	.00211				

(1) $E_D + \eta_D$ @ 1075 °F

(2) $E_D + \eta_D$ @ 1025 °F

TABLE 18

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M22

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1600	1		13.40	13.20	13.61	0.41	.0307	.0167				
	2		91.51	90.74	92.61	1.87	.0204					
	3	244.70	238.70	236.78	240.32	3.54	.0148	.0107	2.41	0.363	2.924	.0806
	4	475.50	470.10	467.62	472.30	4.68	.0194	.0159	2.37	1.06	4.342	.4190
	5	793.50	782.00	773.40	789.83	16.43	.0210	.0175	2.41	0.692	7.401	.8280
	6	1185.00	1183.60	1173.57	1189.34	15.77	.0133	.0120	2.41	1.64	3.433	.2080
1500	1		13.90	13.70	14.14	0.44	.0319	.0179				
	2											
	3	247.60	244.40	240.38	246.66	6.27	.0257	.0242	2.47	1.00	6.753	.6740
	4	486.50	482.00	485.89	477.26	8.63	.0349	.0290	2.48	1.24	7.016	.5650
	5	806.00	804.46	789.08	815.59	26.50	.0330	.0298	2.49	1.69	8.826	.5210
	6		1196.30	1187.65	1201.35	13.70	.0223	.0216				
1450	1		14.06	13.89	14.29	0.397	.0282	.0152				
	2											
	3		247.90	242.55	250.85	8.30	.0335	.0324				
	4		491.50	486.26	494.73	8.47	.0336	.0256				
	5	812.00	818.60	801.90	829.39	28.30	.0346	.0317	2.53	2.24	9.273	.4380
	6		1200.60	1188.78	1209.19	20.40	.0170	.0166				
1400	1											
	2											
	3	251.40	252.10	245.97	255.25	9.30	.0368	.0358	2.54	1.97	10.800	.5470
	4	495.00	499.80	495.02	503.27	8.25	.0322	.0242	2.57	2.44	7.840	.3210
	5	818.50	832.00	816.26	842.53	26.30	.0316	.0288	2.57	2.84	9.802	.3260
	6		1205.70	1194.74	1215.66	20.90	.0173	.0170				
1350	1		14.47	14.25	14.74	0.49	.0338	.0228				
	2											
	3	254.40	256.60	250.76	259.46	8.69	.0339	.0329	2.61	2.38	10.451	.4380
	4	499.00	508.10	500.15	513.66	13.50	.0266	.0216	2.61	3.03	6.867	.2261
	5	824.50	846.10	833.40	853.83	20.40	.0241	.0216	2.61	3.50	7.176	.2050
	6		1210.20	1199.04	1221.45	22.40	.0185	.0182				
1300	1		14.71	14.34	15.07	0.73	.0497	.0400				
	2											
	3	255.20	261.24	257.22	263.78	6.56	.0250	.0243	2.62	3.38	8.335	.2470
	4	502.60	516.30	511.12	520.37	9.26	.0179	.0140	2.64	3.63	5.101	.1400
	5	830.70	858.40	851.21	864.28	13.17	.0153	.0130	2.64	4.04	4.501	.1110
	6		1213.90	1200.05	1228.65	28.60	.0236	.0233				
1250	1		15.00	14.73	15.38	0.64	.0430	.0343				
	2											
	3	257.10	265.60	262.78	267.33	4.55	.0171	.0164	2.66	4.04	5.562	.1380
	4	506.20	522.90	519.40	525.90	6.50	.0124	.00853	2.68	4.08	2.948	.0720
	5	836.80	868.40	863.63	872.52	6.90	.01024	.00824	2.68	4.64	2.675	.0600
	6		1299.50	1293.50	1304.80	11.30	.0087	.00845				

TABLE 18 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M22

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1200	1		15.34	15.14	15.65	0.50	.0327	.0272				
	2											
	3	258.90	269.30	267.81	270.45	2.63	.00979	.0090	2.70	4.53	2.873	.0710
	4	509.60	529.10	527.29	531.07	3.78	.00714	.0028	2.72	4.47	1.083	.0240
	5	842.50	878.30	875.66	880.75	5.10	.0058	.0041	2.72	4.76	1.498	.0314
	6	1256.30	1313.20	1310.10	1316.14	6.03	.00459	.0042	2.71	4.95	1.549	.0310
1150	1		15.62	15.49	15.81	0.32	.0204	.0137				
	2											
	3	260.60	271.96	271.16	272.70	1.54	.00568	.00493	2.74	4.90	1.806	.0370
	4	513.00	533.70	532.59	534.87	2.28	.00427	.00077	2.76	4.71	0.310	.0066
	5	848.20	885.30	883.70	887.08	3.37	.00381	.00234	2.76	4.95	0.819	.0165
	6	1272.00	1323.20	1321.18	1325.20	4.00	.00304	.00279	2.77	4.72	1.039	.0220
1100	1											
	2											
	3	262.30							2.77	5.10	1.033	.0202
	4	516.10							2.79	4.90	0.161	.0033
	5	853.50							2.79	5.10	0.416	.0082
	6											
1050	1		15.99	15.90	16.06	0.16	.00974	.00374				
	2											
	3	263.90	276.30	275.99	276.59	0.60	.00218	.00159	2.80	5.28	0.0611	.0116
	4	519.00	541.60	541.10	542.06	0.97	.00179	.00287	2.82	5.04	0.0110	.0022
	5	858.50	898.20	897.42	898.96	1.53	.00170	.0005	2.83	5.22	0.0211	.0040
	6		1341.60	1340.66	1342.64	1.98	.00148	.00128				
1000	1											
	2											
	3	265.40							2.84	5.41	0.0426	.0079
	4	522.00							2.85	5.10	0.0886	.0017
	5	863.50							2.86	5.31	0.214	.0023
	6											

TABLE 19

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M14

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_L Hz	F_R Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1500	1	13.97	12.04	11.86	12.23	0.374	.03105	.01680				
	2	87.50	85.37	85.13	85.59	0.46	.00538	.00140	2.33	4.90	0.358	.0593
	3	245.20	239.71	239.30	240.14	0.839	.00350	.00186	2.41	0.593	0.484	.0685
	4	480.30	471.70	470.89	472.57	1.68	.00356	.00159				
	5	807.70	781.10	779.48	782.72	3.23	.00414	.00318	2.49	0.136		.5090
	6	1193.70	1168.60	1165.90	1171.10	5.20	.00445	.00378	2.43	0.66	1.024	.1300
1450	1		13.01	12.85	13.20	0.356	.02740	.01640				
	2		86.25	86.05	86.43	0.38	.00440	.00100				
	3	246.95	241.70	241.28	242.15	0.871	.00360	.00250	2.44	0.652	0.632	.0812
	4	803.20	475.50	474.59	476.49	1.90	.00399	.00301				
	5		787.30	785.18	789.17	4.00	.00508	.00421	2.48	0.645	1.141	.1320
	6	1202.70	1177.60	1173.97	1181.03	7.06	.00599	.00539	2.51	0.592	1.441	.1780
1400	1		13.31	13.21	13.47	0.35	.02616	.01580				
	2	88.90	86.94	86.74	87.11	0.37	.00426	.00186	2.40	0.607	0.494	.0661
	3	246.95	243.60	243.07	244.09	1.02	.00419	.00319	2.48	0.679	0.879	.1090
	4		479.40	480.61	478.01	2.60	.00542	.00302				
	5	803.20	793.50	790.51	796.31	5.79	.00730	.00653	2.50	0.763	1.726	.1900
	6	1202.70	1187.90	1181.60	1192.60	11.00	.00925	.00868	2.54	0.669	2.365	.2650
1350	1		12.65	12.51	12.80	0.291	.02300	.01500				
	2	89.62	87.52	87.28	87.70	0.413	.00472	.00242	2.44	0.555	0.651	.0953
	3	248.80	245.60	244.83	246.24	1.40	.00572	.00484	2.52	0.715	1.311	.1540
	4		483.30	481.28	485.15	3.88	.00802	.00542				
	5	809.00	800.20	795.23	804.57	9.34	.01170	.01100	2.53	0.821	2.966	.3030
	6	1211.70	1198.00	1188.30	1206.85	18.57	.01550	.01500	2.54	0.815	4.152	.4250
1300	1	14.48	12.59	12.46	12.76	0.304	.02410	.0163				
	2	90.30	88.17	87.85	88.40	0.55	.00625	.00365	2.48	0.556	0.996	.1450
	3	252.60	247.59	246.43	248.57	2.14	.00866	.00788	2.56	0.750	2.176	.2430
	4	494.00	487.64	484.10	490.82	6.72	.01380	.01060				
	5	821.10	808.10	799.04	814.86	15.82	.01960	.01900	2.57	0.944	5.332	.4730
	6	1229.30	1211.20	1193.64	1226.75	33.10	.02733	.0268	2.62	0.971	7.665	.6380
1250	1		14.21	14.09	14.33	0.239	.02520	.01755				
	2	90.97	89.11	88.85	89.31	0.46	.01010	.00777	2.52	0.709	2.181	.2500
	3	254.50	250.00	247.90	251.91	4.01	.01604	.01530	2.60	0.864	4.305	.4180
	4		492.80	486.48	498.63	12.15	.02460	.02120				
	5	827.80	818.13	801.15	830.15	29.00	.03540	.03490	2.61	1.16	10.108	.7280
	6	1237.90	1234.10	1205.20	1254.26	49.10	.03977	.03930	2.62	1.59	11.621	.6090
1200	1		14.60	14.48	14.74	0.254	.01740	.01010				
	2	91.60	89.87	89.37	90.29	0.938	.02010	.01800	2.55	0.793	5.126	.5250
	3	256.40	253.17	248.56	256.56	8.00	.03160	.03090	2.64	1.13	8.959	.6670
	4		502.20	491.21	510.15	18.90	.03770	.03370				
	5	834.00	834.70	809.39	849.91	40.52	.04850	.00481	2.65	1.81	14.601	.6700
	6	1247.00	1261.70	1237.50	1284.03	46.60	.03690	.03650	2.69	2.61	11.847	.4160

TABLE 19 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M14

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_L Hz	F_R Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1150	1		16.21	16.05	16.30	0.31	.01410	.01290				
	2											
	3	258.10	258.90	252.39	263.55	11.15	.04310	.04240	2.67	1.94	13.049	.5650
	4	510.00	514.48	504.31	522.47	18.15	.03530	.03100	2.71	2.26	10.183	.3760
	5	839.80	859.00	844.38	870.47	26.10	.03040	.03000	2.69	2.29	11.585	.3210
	6	1255.60	1289.30	1269.20	1306.93	37.70	.02927	.02880	2.73	3.62	9.710	.2520
1100	1	14.84	15.84	16.07	15.60	0.47	.02980	.02390				
	2	92.89										
	3	259.90	265.90	260.68	269.86	9.18	.03450	.03390	2.71	3.03	11.221	.3110
	4	512.60	525.50	518.30	531.70	13.36	.02540	.02040	2.74	3.17	6.916	.1820
	5	845.00	873.10	862.22	880.82	18.61	.02130	.02090	2.72	3.60	7.215	.1670
	6	1264.00	1311.00	1298.50	1322.40	23.90	.01820	.01780	2.76	3.83	6.296	.1370
1050	1		15.81	15.48	16.14	0.67	.04240	.03690				
	2											
	3	261.50	271.40	268.36	274.16	5.80	.02140	.02080	2.74	3.89	7.279	.1570
	4	515.20	533.70	529.72	537.52	7.80	.01460	.00962	2.77	3.81	3.377	.0740
	5	849.80	886.10	879.74	891.50	11.76	.01330	.01280	2.76	4.18	4.216	.0842
	6	1271.90	1327.30	1320.13	1334.20	14.10	.01061	.01020	2.76	4.24	3.681	.0722
1000	1	15.01	16.86	16.59	17.23	0.64	.03780	.03260				
	2	94.00	98.50	97.79	99.46	1.61	.01633	.00593	2.69	4.37	2.556	.0470
	3	263.00	275.50	273.95	277.13	3.18	.01150	.01100	2.77	4.49	4.006	.0750
	4	517.20	540.20	538.07	542.53	4.47	.00827	.00327	2.79	4.33	1.454	.0280
	5	854.80	896.00	892.54	899.04	6.50	.00725	.00685	2.79	4.55	2.535	.0465
	6	1278.90	1341.60	1337.10	1346.10	9.00	.00671	.00630	2.79	4.61	2.336	.0421
950	1		16.03	15.85	16.28	0.43	.02690	.02210				
	2		99.35	98.96	99.85	0.89	.00895	.00800				
	3		278.40	277.45	279.30	1.85	.00665	.00600				
	4		545.30	543.69	546.93	3.24	.00594					
	5		903.90	901.71	906.21	4.50	.00497	.00450				
	6		1353.50	1350.60	1356.90	6.23	.00460	.00430				

TABLE 20

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M48

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1500	2	95.15	92.70	92.47	92.96	0.49	.00529	.00169	2.36	0.419	0.363	.0866
	3	266.50	260.20	259.76	260.66	0.90	.00350	.0015	2.44	0.530	0.335	.0633
	4	523.50	514.77	513.61	515.97	2.36	.00458	.00338	2.45	0.854	0.774	.0907
	5	868.00	846.50	845.02	848.10	3.08	.00364	.0026	2.47	0.483	0.585	.1210
	6	1299.50	1268.30	1265.76	1270.33	4.57	.0036	.0029	2.48	0.521	0.658	.1260
1450	2	95.92	93.48	93.31	93.69	0.38	.00411	.00131	2.40	0.440	0.286	.0651
	3	268.70	262.20	261.76	262.66	0.90	.00344	.0020	2.48	0.513	0.454	.0885
	4	527.50	518.24	517.14	519.53	2.39	.00461	.00374	2.49	0.826	0.867	.1050
	5	875.00	853.00	851.21	854.77	3.57	.00418	.00328	2.51	0.473	0.749	.1580
	6	1309.50	1277.80	1274.96	1280.39	5.44	.00425	.00365	2.52	0.520	0.840	.1620
1400	2	96.69	94.24	94.07	94.42	0.346	.00368	.00143	2.44	0.452	0.318	.0704
	3	270.85	264.24	263.75	264.76	1.01	.00383	.00263	2.52	0.510	0.606	.1190
	4	531.60	522.30	520.991	523.70	2.70	.00517	.00460	2.53	0.841	0.108	.1290
	5	881.60	859.77	857.19	862.07	4.88	.00567	.00487	2.54	0.499	0.113	.2270
	6											
1350	2	97.40	94.99	94.78	95.18	0.406	.00427	.0025	4.00	0.485	0.565	.1160
	3	272.90	266.30	265.73	266.94	1.20	.00453	.00363	2.56	0.53	0.85	.1600
	4	535.70	526.80	524.88	528.82	3.94	.00748	.00692	2.56	0.897	0.166	.1850
	5	888.00	866.85	836.11	870.40	7.29	.00841	.00766	2.58	0.551	0.181	.3280
	6	1329.00	1298.80	1291.26	1304.77	13.50	.0104	.00995	2.59	0.607	2.37	.3900
1300	2	98.20	95.98	95.74	96.24	0.50	.00518	.0037	2.51	0.595	0.855	.1440
	3	275.00	268.67	267.73	269.59	1.85	.0069	.00611	2.60	0.595	0.146	.2450
	4	539.80	531.50	528.88	534.36	5.48	.0103	.00983	2.60	0.972	0.240	.2470
	5	894.70	874.70	868.36	880.75	12.40	.0142	.0134	2.62	0.632	0.332	.5110
	6	1339.00	1309.80	1295.09	1320.85	25.76	.0197	.0193	2.63	0.662	4.68	.7070
1250	2	98.90	96.59	96.25	96.96	0.71	.00734	.00614	2.55	0.567	1.44	.2530
	3	277.00	271.10	269.56	272.62	3.06	.0113	.0106	2.64	0.689	2.58	.3740
	4	543.60	537.10	532.79	541.83	9.03	.0168	.0164	2.64	1.66	4.11	.3540
	5	901.00	884.70	873.82	893.73	19.91	.0225	.0218	2.66	0.854	5.39	.6310
	6	1348.90	1324.90	1315.65	1333.71	18.06	.0266	.0262	2.67	0.875	6.52	.7460
1200	2	99.65	97.65	96.99	98.31	1.32	.0135	.0125	2.59	0.736	3.00	.4070
	3	279.00	274.50	271.51	277.39	5.88	.0214	.0208	2.68	0.961	5.21	.5430
	4	547.50	546.20	538.88	554.82	15.94	.0292	.0287	2.68	1.67	7.50	.4480
	5	907.80	899.50	880.20	913.74	33.54	.0373	.0366	2.70	1.38	9.43	.7100
	6	1358.90	1346.30	1330.21	1362.40	32.19	.0466	.0461	2.71	1.33	11.90	.8980
1150	2	100.38	99.87	97.63	100.12	2.49	.0252	.0243	2.63	1.50	6.18	.4110
	3	281.00	279.40	274.62	284.26	9.64	.0345	.0339	2.71	1.52	8.88	.5850
	4	551.30	558.70	549.54	570.03	20.49	.0367	.0363	2.72	2.55	10.10	.3950
	5	914.00	926.40	906.18	946.10	39.30	.0424	.0420	2.73	2.57	11.70	.4600
	6											

TABLE 20 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M48

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1100	2	101.20	100.99	98.71	102.98	4.27	.0423	.0413	2.67	1.68	10.80	.6390
	3	283.00	286.45	281.41	291.48	10.07	.0351	.0345	2.75	2.51	9.66	.3840
	4	555.20	570.70	563.13	580.48	17.40	.0304	.0300	2.76	3.40	8.80	.2590
	5	920.40	946.20	937.38	956.66	19.28	.0204	.0197	2.77	3.43	5.82	.1700
	6											
1050	2	101.80	104.11	102.16	106.06	3.91	.0375	.0365	2.70	3.04	10.40	.3400
	3	284.90	292.89	289.30	296.50	7.20	.0246	.0240	2.79	3.45	0.713	.2070
	4	558.80	580.60	575.47	586.27	10.80	.0186	.0182	2.79	4.09	5.59	.1370
	5	926.30	958.90	950.57	965.00	15.43	.0161	.0154	2.81	3.89	4.70	.1210
	6	1387.00	1439.50	1434.39	1444.69	10.22	.0138	.0133	2.82	4.07	4.12	.1011

TABLE 21

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M5

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1500	2	89.99	87.20	87.14	87.61	0.47	.000542	.00082	2.34	0.147		.1240
	3	251.50	245.10	244.65	245.62	0.973	.00397	.00207	2.41	0.46		.1160
	4	493.70	479.00	478.27	481.39	3.12	.00442	.00262	2.41	0.21		.2900
	5	818.30	795.80	793.40	798.02	4.56	.0057	.00483	2.43	0.157		.7120
	6		1190.80	1186.24	1194.74	8.50	.0071	.0062				
1450	2	90.70	88.03	87.83	88.21	0.387	.0044	.0013	2.45	1.08	0.304	.0281
	3	253.50	246.87	246.39	247.45	1.06	.00429	.00301				
	4	497.50	483.98	482.67	485.44	2.76	.00571	.00441				
	5	824.80	801.86	798.47	805.15	6.69	.00834	.00748				
	6	1234.30	1200.80	1193.30	1206.30	13.00	.0018	.0101				
1400	2	91.38	88.12	87.92	88.34	0.416	.00472	.00207	2.41	0.0862	0.592	.6640 (1)
	3	255.50	247.33	246.74	247.91	1.17	.00475	.00364	2.48	0.199	1.105	.5550 (1)
	4	501.30	484.90	483.28	486.57	3.30	.00679	.00551	2.49	0.239	1.838	.7680 (1)
	5	831.00	803.50	799.49	807.36	7.87	.0098	.00893	2.50	0.239	2.928	1.2300 (1)
	6	1243.40	1201.90	1192.90	1210.07	17.20	.0143	.0137	2.51	0.283	4.193	1.4700 (1)
1350	1	14.68	14.34	14.29	14.39	0.105	.00731	.00031	2.52	0.551	0.740	.0130
	2	92.07	89.22	88.95	89.50	0.55	.00610	.00396	2.45	0.162	0.965	.5770
	3	257.40	250.30	249.19	251.43	2.24	.00896	.00811	2.71	0.252	1.965	.7320
	4	505.00	491.20	487.52	495.10	7.58	.0154	.0140	2.52	0.333	3.483	1.0460
	5	837.20	813.50	804.44	822.57	18.13	.0223	.0214	2.54	0.385	5.282	1.3700
	6	1252.60	1223.10	1200.90	1245.33	44.24	.0363	.0358	2.54	0.385	6.986	1.3050
1300	1	14.72	14.45	14.38	14.52	0.138	.00953	.00313	2.53	0.799		.0765
	2	92.75	90.08	89.66	90.52	0.860	.00955	.00725	2.48	0.265	1.797	.6560
	3	259.20	252.90	250.99	255.00	4.00	.0159	.01514	2.56	0.383	3.731	.9750
	4	508.70	497.90	491.76	505.41	13.60	.0274	.0259	2.56	0.699	6.461	.9230
	5	843.60	826.20	809.13	839.42	30.30	.0367	.0358	2.58	0.621	8.974	1.4400
	6	1262.00	1253.10	1227.70	1278.50	50.80	.0405	.0401	2.58	1.40	11.434	.8090
1250	1	14.80	14.56	14.63	14.47	0.152	.01047	.00467	2.56	0.918	1.151	.1250
	2	93.46	91.00	90.24	91.91	1.68	.0184	.0162	2.52	0.366	3.775	.9990
	3	261.10	256.40	252.68	260.13	7.45	.0291	.0284	2.59	0.756	6.913	.9140
	4	512.30	509.30	498.45	520.21	21.76	.0427	.0412	2.60	1.47	11.217	.7610
	5	849.80	840.13	819.27	860.55	41.30	.0491	.0483	2.62	1.25	12.984	1.0400
	6	1271.00	1303.80	1277.10	1377.90	40.70	.0609	.0605	2.62	3.18	16.566	.5180
1200	1	14.95	14.65	14.54	14.76	0.213	.0145	.00911	2.61	0.733	7.483	.3160
	2	94.16	93.41	91.59	94.55	2.96	.03171	.0293	2.56	0.528	7.321	.1340
	3	263.00	262.00	256.70	267.53	10.80	.0413	.0408	2.63	0.161	11.155	.6910
	4	515.90	525.70	512.27	539.23	27.40	.05128	.0499	2.63	0.283	17.439	.6150
	5	856.00	866.40	844.24	883.55	39.30	.0454	.0447	2.65	0.249	13.509	.5410
	6	1279.80	1319.30	1292.30	1346.10	53.80	.0408		2.65	0.377	12.639	.3330

TABLE 21 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M5

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1150	1	15.13	14.84	14.65	15.10	0.456	.0307	.0256	2.68	0.80		.8270
	2	94.84	94.12	93.25	95.02	1.77	.01883	.0166	2.60	0.808	11.420	1.3700
	3	264.90	269.40	263.58	274.93	11.35	.04211	.0369	2.67	0.283	11.160	.3940
	4	519.50	535.60	525.98	547.98	22.00	.04107	.0398	2.67	0.368	12.271	.3330
	5	862.00	888.80					.0290	2.69	0.367	8.946	.2440
	6	1288.80	1340.30	1324.15	1352.08	27.90	.0208	.0205	2.69	0.419	6.521	.1550
1100	1	15.34	15.12	14.78	15.63	0.857	.05668	.0520	2.75	1.09	14.368	1.3100
	2	95.53	94.65	93.64	95.67	2.00	.02139	.0193	2.64	1.18	10.717	.8800
	3	266.70	275.50	271.43	279.43	8.00	.02903	.0285	2.71	3.82	8.298	.2170
	4	522.90	544.30	537.63	551.45	13.82	.0254	.0243	2.71	4.36	9.692	.1760
	5	867.80	902.70	895.74	911.33	15.60	.02727	.0169	2.73	4.34	5.459	.1260
	6	1297.00	1352.10	1344.45	1362.21	17.80	.01314	.0128	2.73	4.54	16.014	.0929
1050	1	15.53	15.85	15.42	16.27	0.849	.0535	.0492	2.82	3.31		.4660
	2	96.15	96.81	95.69	98.47	2.78	.02872	.0269	2.67	2.17	6.303	.2810
	3	268.40	280.30	278.00	282.59	4.59	.01637	.0120	2.74	4.55	4.926	.1080
	4	526.20	552.00	547.65	556.42	8.78	.0159	.0149	2.74	5.00	5.268	.1050
	5	873.30	915.60	909.92	920.30	10.40	.01134	.01105	2.76	4.84	3.597	.0742
	6	1305.00	1369.50	1363.90	1376.80	13.00	.00946	.00919	2.76	4.90	2.952	.0598
1000	1	15.66	16.22	15.98	16.51	0.53	.0327	.0287	2.87	4.20	9.338	.2220
	2	96.73	101.62	100.92	102.31	1.39	.0137	.01206	2.70	4.86	4.057	.0828
	3	270.00	283.50	282.02	284.81	2.79	.00983	.00941	2.77	4.99	3.024	.0606
	4		557.40	554.20	561.07	6.87	.01233	.01136				
	5	878.20	924.30	921.06	927.13	6.06	.00656	.0063				
	6		1382.60	1378.40	1387.50	9.18	.00664	.0064				

(1) $F_C \rightarrow \eta_C$ @ 1425 °F

TABLE 22

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M27

		Experimental Measurements							Material Properties			
Temp °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1550	2		86.59	85.98	87.41	1.43	.0165	.0117				
	3	241.40	241.10	238.91	243.39	4.48	.0186	.0159	2.33	1.73	6.94	.4000
	4	474.00	475.20	470.06	480.31	10.30	.0216	.0197	2.34	2.07	8.53	.4120
	5	786.00	786.25	774.29	796.24	21.90	.02792	.0252	2.35	1.89	1.13	.5960
	6	1175.20	1186.20	1163.50	1204.50	41.06	.0346	.02337	2.36	2.54	1.04	.4080
1500	2	87.00	87.12	86.42	87.83	1.40	.0161	.0126	2.30	1.72	5.48	.3190
	3	243.20	244.10	241.45	246.73	5.28	.0216	.0198	2.36	2.30	8.93	.4060
	4	475.50	481.40	475.08	487.00	11.92	.0248	.0234	2.35	2.96	11.10	.3760
	5		797.30	774.23	808.87	34.60	.0434	.0411				
	6		1203.40	1169.70	1222.70	52.90	.0440	.0431				
1450	2	87.80	87.99	87.05	88.88	1.83	.0208	.0182	2.34	2.05	8.05	.3930
	3	245.00	247.70	244.21	251.08	6.87	.0277	.0264	2.40	2.90	12.10	.4160
	4	481.00	489.60	486.03	493.34	7.31	.0291	.0281	2.40	3.54	13.30	.3760
	5		812.70	823.59	801.79	21.80	.0268	.0247				
	6	1193.20	1226.40	1216.50	1235.33	18.80	.0299	.0292	2.43	4.52	14.30	.3170
1400	2	88.48	89.26	87.99	90.35	2.36	.0265	.0243	2.37	2.81	11.10	.3960
	3	246.72	251.80	248.02	255.50	7.48	.0297	.0287	2.43	3.87	13.30	.3440
	4	484.50	499.20	492.13	505.41	13.28	.0266	.0257	2.44	4.78	13.00	.2720
	5		826.70	820.08	831.88	11.80	.0278	.0259				
	6	1202.00	1244.70	1229.90	1259.40	29.58	.0238	.0232	2.47	5.35	11.60	.2160
1350	2	89.13	91.07	89.66	92.29	2.63	.0289	.0271	2.41	3.73	12.70	.3400
	3	248.50	256.80	253.49	260.02	6.53	.0254	.0245	2.47	5.06	12.30	.2440
	4		517.00	501.23	511.61	10.40	.0201	.0194				
	5	808.90	841.02	832.15	847.39	15.23	.01811	.0163	2.49	5.89	8.10	.1380
	6	1210.20	1262.90	1253.60	1272.20	18.55	.0147	.0142	2.50	6.09	7.54	.1240
1300	2	89.76	92.33	91.17	93.42	2.26	.0244	.0229	2.44	4.59	11.50	.2490
	3	250.22	260.50	258.08	262.90	4.82	.0185	.0177	2.50	6.00	9.28	.1550
	4	491.50	512.77	509.35	516.26	6.92	.0135	.0129	2.51	5.23	6.85	.1100
	5	814.30	850.70	845.52	855.21	9.69	.0114	.00961	2.52	6.41	5.19	.0809
	6	1218.80	1275.70	1269.80	1281.70	11.88	.00931	.00892	2.54	6.65	4.86	.0730
1250	2	90.38	93.54	92.71	94.38	1.66	.0178	.0163	2.48	5.32	8.50	.1600
	3	252.00	263.50	261.97	265.03	3.07	.0116	.0109	2.54	6.57	5.89	.0900
	4	495.00	518.00	515.97	520.18	4.21	.00814	.00758	2.55	6.65	4.17	.0630
	5	819.70	859.40	856.31	862.14	5.83	.00679	.00509	2.56	6.89	2.82	.0410
	6	1227.00	1287.70	1284.11	1291.49	7.40	.00573	.00537	2.57	7.03	3.07	.0440
1200	2	90.98	99.14	98.59	100.15	1.56	.0158		2.51	5.99	5.42	.0905
	3	253.65	266.30	265.46	267.29	1.84	.0069	.00609	2.57	7.06	3.47	.0490
	4	497.70	522.90	521.57	524.19	2.62	.00502	.00445	2.57	7.17	2.55	.0360
	5	825.00	866.80	864.83	868.66	3.83	.00442	.0028	2.59	7.22	1.50	.0207
	6	1235.00	1297.90	1295.80	1300.90	5.06	.0039	.00357	2.60	7.35	1.94	.0260

TABLE 22 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M27

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1150	2	91.54	95.81	95.49	96.14	0.65	.0068	.0054	2.54	6.57	2.95	.0449
	3	255.40	268.60	268.02	269.24	1.22	.00454	.00364	2.61	7.38	2.00	.0270
	4	501.40	527.30	526.48	528.18	1.70	.00322	.00276	2.61	7.39	1.54	.0209
	5	830.50	874.10	872.91	875.35	2.45	.00280	.0013	2.62	7.51	0.748	.00996
	6	1243.00	1309.20	1307.80	1311.00	3.20	.00245	.00215	2.64	7.63	1.22	.0160
1100	2	92.10	96.60					.00252	2.57	6.98	1.41	.0202
	3	257.00						.0019				
	4											
	5	835.70						.00066				
	6	1250.50						.00138				
1050	2	92.64	97.33	97.21	97.48	0.27	.0028	.00122	2.60	7.25	0.692	.0096
	3	258.55	272.70	272.39	272.99	0.59	.00218	.00096	2.67	7.90	0.566	.0072
	4		535.00	534.64	535.36	0.72	.00134	.00095				
	5	840.70	886.50	885.98	887.23	1.26	.00142	.000219	2.69	7.92	0.131	.00165
	6	1258.00	1327.70	1326.96	1328.55	1.59	.00120	.00093	2.70	8.06	0.556	.0069
950	2		98.47	98.37	98.66	0.29	.00294	.00094				
	3		276.00	275.81	276.23	0.42	.00152					
	4		541.01	540.77	541.33	0.56	.00103	.0007				
	5		896.40	895.82	896.86	1.04	.00117	.00039				
	6		1342.10	1341.20	1342.60	1.44	.00107	.00082				

TABLE 23

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M31

Temp. °F	Mode	Experimental Measurements F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	Material Properties E_M psi $\times 10^{-7}$	E_{DR} psi $\times 10^{-6}$	E_{DI} psi $\times 10^{-6}$	η_D
1650	2	82.60	80.59	80.38	80.84	0.46	.0112	.0022	2.22	0.355	0.692	.1950
	3	232.40	226.30	225.80	226.84	1.04	.00895	.00295	2.31	0.274	0.717	.2620
	4	457.00	446.40	44.76	448.55	3.79	.00849	.00349	2.33	0.430	0.864	.2010
	5	758.00	739.40	736.27	742.39	6.12	.00828	.00403	2.34	0.364	0.990	.2720
	6	1134.50	1106.90	1101.26	1111.51	10.30	.00926	.0066	2.35	0.377	1.64	.4360
1600	2	83.35	81.34					.0035	2.26	0.372	0.836	.2250
	3	234.50	228.70					.0039	2.36	0.356	0.970	.2720
	4	460.90	448.50					.0059	2.37	0.247	1.46	1.5930
	5	1143.80						.0108				
	6											
1550	2	84.08	82.05	81.67	82.52	0.85	.0103	.00435	2.30	0.407	1.06	.2610
	3	236.40	230.90	229.82	231.74	1.92	.0083	.0058	2.39	0.438	1.45	.3300
	4	464.50	454.10	448.31	457.64	9.34	.0206	.0182	2.40	0.228	2.52	1.1030
	5	767.50	753.40	748.22	758.32	10.10	.0134	.0119	2.40	0.396	2.31	.5840 (1)
	6		1127.70	1116.20	1137.00	20.80	.01843	.0174				
1500	2	84.78	82.88	82.54	83.34	0.80	.00963	.00573	2.34	0.489	1.42	.2900
	3		232.80	231.62	233.92	2.30	.00989	.00809				
	4		457.80	454.57	462.80	8.20	.0180	.0168				
	5	773.60	760.70	753.98	767.99	14.01	.01842	.0175	2.44	0.474	4.07	.8580 (2)
	6	1161.80	1449.50	1435.10	1446.30	31.14	.0215	.0207	2.47	0.774	7.73	.9990
1450	2	85.46	83.79	83.35	84.30	0.96	.0114	.0083	2.37	0.603	2.16	.3580
	3	240.10	235.40	233.35	237.14	3.79	.0161	.0148	2.47	0.628	3.91	.6230
	4	471.80	464.40	459.45	471.23	11.78	.0254	.0244	2.48	0.865	7.37	.8520
	5	779.60	771.50	758.55	783.58	25.00	.0324	.0316	2.48	0.748	6.94	.9280 (3)
	6		1473.80	1454.97	1493.31	37.30	.0253	.0247				
1400	2	86.13	84.55	83.92	85.46	1.53	.0182	.0157	2.41	0.737	4.11	.5570
	3		238.10	234.86	241.10	6.24	.0262	.0251				
	4		472.20	464.51	483.30	18.80	.0398	.0389				
	5	785.50	785.40	763.50	800.13	36.60	.0466	.0458	2.52	0.124	10.50	.8180 (4)
	6		1296.80	1283.20	1311.80	28.62	.0221	.0215				
1350	2	86.81	85.86	84.81	87.75	2.94	.0342	.0318	2.45	0.114	8.63	.7590
	3	243.75	241.80	237.03	245.92	8.89	.0368	.0360	2.55	1.32	10.30	.7800
	4	478.90	483.70	473.89	495.69	21.80	.0451	.0443	2.55	2.31	13.10	.5670
	5	791.40	804.20	811.82	794.60	17.22	.0418	.0410	2.55	2.05	12.20	.5940 (5)
	6		1298.40	1291.82	1306.17	14.34	.0215	.0210				
1325	2		86.82	85.50	88.82	3.32	.0382	.0350				
	3		243.90	238.82	248.66	9.84	.0403	.0396				
	4		487.80	481.05	502.06	21.00	.0431	.0423				
	5	797.30	812.10	796.24	827.75	31.50	.0388	.0380	2.59	2.97	11.80	.4000
	6		1328.70	1314.50	1343.00	28.50	.0419	.0414				

TABLE 23 (CONTINUED)
EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M31

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1300	2		87.67	86.28	89.55	3.27	.0373	.0350				
	3	245.50	245.80	240.12	251.46	11.35	.0462	.0455	2.58	1.90	13.30	.6970
	4	482.50	494.10	486.78	505.51	18.73	.0379	.0372	2.59	3.23	12.00	.3720
	5		821.30	807.62	834.58	26.96	.0328	.0322				
	6											
1250	2	88.13	89.65	88.09	91.20	3.11	.0347	.0325	2.52	2.87	12.70	.4430
	3	247.30	254.60	251.26	257.10	5.85	.0448	.0442	2.62	3.64	14.00	.3830
	4	485.80	503.20	497.24	510.67	13.40	.0267	.0260	2.63	4.03	8.62	.2140
	5	803.50	835.90	827.06	845.02	18.00	.0215	.02101	2.63	3.78	8.86	.2340 [6]
	6											
1200	2	88.78	91.63	89.99	92.87	2.87	.0314	.0294	2.56	3.77	9.46	.2510
	3	249.05	259.40	256.77	262.94	6.17	.0238	.0232	2.66	4.45	7.50	.1690
	4	489.20	510.40	506.48	514.59	8.11	.0159	.0153	2.66	4.62	5.16	.1120
	5	808.50	847.30	841.90	852.90	11.00	.0130	.0125	2.66	4.48	5.54	.1240 [7]
	6	1213.70	1271.30	1265.70	1278.10	12.50	.0098	.0094	2.70	5.00	3.42	.0689
1150	2	89.40	93.15	92.29	94.01	1.73	.0185	.0167	2.60	4.44	5.52	.1250
	3	250.80	262.70	261.19	264.23	3.04	.0116	.0111	2.69	4.90	3.87	.0790
	4	492.40	516.72	513.87	519.00	5.12	.0099	.0093	2.70	5.07	2.95	.0580
	5	814.00	856.86	853.53	859.77	6.24	.0073	.0069	2.70	4.94	3.28	.0660 [8]
	6		1284.40	1280.08	1288.00	7.91	.0062	.0059				
1100	2	90.00	94.29	93.79	94.74	0.95	.0101	.0086	2.63	4.84	2.96	.0612
	3	252.40	265.30	264.48	266.18	1.70	.0064	.0059	2.73	5.26	2.09	.0400
	4	495.60	521.65	520.40	522.90	2.50	.0048	.0042	2.74	5.36	1.65	.0310
	5	819.40	864.50	862.52	866.33	3.81	.0044	.0040	2.74	5.26	1.92	.0360 [9]
	6	1226.00	1295.30	1292.82	1297.70	4.87	.0038	.0035	2.75	5.35	1.57	.0293 [10]
1050	2	90.60	95.13	94.84	95.41	0.57	.0060	.0046	2.67	4.96	1.64	.0332
	3	254.00	267.80	267.27	268.26	1.00	.0037	.0032	2.76	5.54	1.20	.0220
	4	498.60	526.20	525.38	526.98	1.61	.0031	.0025	2.77	5.62	0.926	.0160
	5	824.50	872.00	870.63	873.13	2.51	.0029	.0025	2.77	5.50	1.16	.0210 [11]
	6	1233.80	1306.20	1304.46	1307.70	3.24	.0025	.0022	2.79	5.59	1.00	.01[illegible]0 [12]
1000	2	91.50						.00295				
	3	255.60	270.15					.0014	2.80	5.79	5.26	.0090
	4	500.10	528.30					.0019	2.78	5.73	7.10	.0120
	5	829.80	875.00					.00215	2.81	5.63	8.05	.0143 [13]
	6							.0019				
950	2		96.44	96.30	96.60	0.30	.0031	.0021				
	3		271.60	271.37	271.85	0.48	.0018	.0014				
	4		533.50	533.05	533.90	0.85	.0016	.0010				
	5		882.92	881.91	883.86	1.87	.0021	.0017				
	6		1322.40	1321.35	1323.63	2.27	.0017	.0015				

TABLE 23 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M31

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-5}$	E_{DI} PSI $\times 10^{-5}$	η_D
850	2		97.94									
	3		274.62									
	4		539.03									
	5		892.90									
	6		1337.10									

(1) $E_D + \eta_D$ @ 1275 °F

(2) $E_D + \eta_D$ @ 1225 °F

(3) $E_D + \eta_D$ @ 1175 °F

(4) $E_D + \eta_D$ @ 1125 °F

(5) $E_D + \eta_D$ @ 1125 °F

(6) $E_D + \eta_D$ @ 1075 °F

(7) $E_D + \eta_D$ @ 1075 °F

(8) $E_D + \eta_D$ @ 1575 °F

(9) $E_D + \eta_D$ @ 1525 °F

(10) $E_D + \eta_D$ @ 1475 °F

(11) $E_D + \eta_D$ @ 1425 °F

(12) $E_D + \eta_D$ @ 1375 °F

(13) $E_D + \eta_D$ @ 1025 °F

TABLE 24

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M4

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1600	1	14.12	13.85	13.74	13.96	0.221		.00290	2.36			
	2	88.10	88.43	89.03	87.77	1.27	.0143	.00332	2.27	2.28	1.858	.0790
	3	246.90	250.20	248.27	252.05	3.79	.0151	.01100	2.35	3.49	6.399	.1830
	4	485.20	491.70	485.74	494.83	9.09	.0185	.01580	2.36	3.48	9.238	.2050
	5		815.50	809.52	821.49	12.00	.0147	.01230				
	6											
1550	1	14.24	14.09					.00610	2.41	8.30	3.374	.4050
	2	88.84	89.40					.00720	2.31	2.64	4.159	.1530
	3	249.08	253.30					.01270	2.40	3.97		.1920
	4	497.50	489.20					.01670	2.40	3.98		.2520
	5											
	6											
1500	1	[illegible].36	14.30	14.16	14.45	0.288	.0202	.00917	2.45	1.57	5.221	.3320
	2	89.60	90.54	89.85	91.28	1.44	.0159	.01160	2.35	3.11	7.490	.2330
	3	251.10	256.40	254.42	258.32	3.90	.0152	.01340	2.43	4.55	8.200	.1800
	4	493.00	503.90	497.74	506.94	9.21	.0183	.01670	2.44	4.69	10.310	.2190
	5	817.60	835.30	832.29	839.21	6.91	.00828	.00680	2.46	4.72	4.312	.0913
	6	1223.50	1246.30	1241.46	1252.02	10.60	.00848	.00734	2.46	4.29	4.607	.1070
1450	1	14.57	14.51	14.37	14.66	0.289	.0199	.01050	2.49	2.25	6.190	.2760
	2	90.32	91.64	90.92	92.47	1.55	.01695	.01360			2.330	
	3	253.00	259.50	257.73	261.12	3.40	.0131	.01170	2.47	5.17	7.742	.1500
	4	496.80	510.52	506.89	515.19	8.30	.01627	.01490	2.48	5.39	9.609	.1780
	5	823.80	847.00	844.67	849.83	5.20	.0061	.00498	2.49	5.54	5.107	.0921
	6	1231.50	1262.00	1256.28	1267.75	11.50	.0091	.00823	2.49	5.05	5.266	.1040
1400	1	14.58	14.68	14.54	14.83	0.288	.0196	.01170	2.52	2.94	7.100	.2410
	2	91.05	92.95	92.17	93.66	1.48	.0160	.01330	2.43	4.36	8.098	.1800
	3	254.90	262.30	260.89	263.76	2.90	.01105	.01000	2.51	5.67	6.509	.1150
	4	500.50	515.80	513.48	520.37	6.89	.0134	.01230	2.90	2.14	7.940	.1360
	5	830.00	853.60	849.83	856.82	6.99	.0082	.00720	2.53	5.75	4.673	.0810
	6	1242.00	1278.90	1275.02	1285.35	10.30	.0081	.00140	2.54	5.42	4.799	.0880
1350	1	14.69	14.86	14.72	15.00	0.28	.01887	.01200	2.56	3.57	7.567	.2110
	2	91.76	94.00	93.45	94.54	1.09	.0116	.00921	2.47	5.04	6.526	.1250
	3		264.90	263.85	266.08	2.24	.00845	.00760				
	4		520.60	518.48	523.42	4.90	.0095	.00859				
	5	836.00	861.80	859.18	864.01	4.80	.0056	.00461	2.57	6.00	3.083	.0514
	6	1251.00	1287.80	1284.52	1291.49	6.97	.0054	.00490			3.433	.0580
1300	1	14.79	15.04					.01000	2.59	4.29		.1510
	2	92.48	95.00					.00700	2.50	5.43	4.676	.0633
	3	258.70	267.30					.00560	2.58	6.39	3.804	.0600
	4	507.80	524.80					.00670	2.59	6.43	4.570	.0710
	5	841.50	868.80					.00310	2.60	6.30	2.117	.0336
	6	1260.00	1300.40					.00350	2.61	6.30	2.409	.0380

TABLE 24 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M4

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1250	1		15.21	15.12	15.31	0.19	.0125	.00678				
	2		95.82	95.52	96.15	0.633	.00661	.00476				
	3		269.70	269.01	270.33	1.32	.00491	.00405				
	4		529.20	527.65	530.81	3.20	.00598	.00530				
	5		867.10	874.70	877.58	2.90	.00329	.00224				
	6		1309.80	1307.87	1311.65	3.77	.00288	.00247				
1200	1	15.00	15.38					.00440	2.67	5.53	3.019	.0540
	2	93.85	96.65					.03230	2.58	5.93	2.240	.0365
	3	262.23	271.94					.00288	2.66	7.08	2.034	.0287
	4	515.00	533.60					.00345	2.66	6.97	2.440	.0350
	5	853.70	883.10					.00163	2.68	6.78	1.153	.0170
	6	1278.00	1320.00					.00160	2.69	6.59	1.136	.0171
1150	1	15.10	15.51					.00275	2.70	5.85	1.923	.0330
	2	94.51	97.46					.00220	2.62	6.20	1.554	.0243
	3	264.30	274.07					.00200	2.70	7.18	1.435	.0200
	4	518.50	537.60					.00245	2.70	7.17		.0245
	5	859.40	890.00					.00121	2.71	7.04	0.870	.0124
	6	1287.00	1324.60					.00110	2.72	6.71	0.792	.0117
1100	1		15.61	15.55	15.65	0.0998	.0064	.00170				
	2		98.21	98.08	98.36	0.28	.00285	.00150				
	3	266.13	276.10	275.83	276.36	0.526	.00191	.00138	2.73	7.35	1.020	.0139
	4	522.20	541.40	540.77	542.03	1.26	.00233	.00155	2.74	7.31	1.276	.0174
	5	865.10	896.00	895.42	896.54	1.12	.00125	.00018	2.75	7.15	0.657	.00918
	6	1296.00	1338.30	1338.30	1339.76	1.43	.00107	.00078			0.585	
1050	1											
	2	95.73	98.98					.00110	2.68	6.73	0.840	.0116
	3	267.84	278.07					.00098	2.77	7.55	0.725	.0096
	4	525.50	544.80					.00120	2.77	7.35		.0120
	5											
	6											

TABLE 25

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M45

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1450	1		15.17	15.06	15.26	0.20	.01303					
	2	96.80	94.96	94.63	95.24	0.60	.00636	.00336	2.42	0.575	1.01	.1750
	3	270.70	265.70	264.58	266.77	2.19	.00824	.00654	2.49	0.627	1.88	.2990
	4	529.00	522.40	519.32	525.29	5.97	.01144	.0105	2.47	1.00	3.29	.3290
	5	879.00	867.70	860.73	873.59	12.90	.01482	.0139	2.50	0.987	4.40	.4450
	6	1323.00	1298.90	1283.70	1309.10	25.40	.0195	.0172	2.54	0.656	5.44	.8290
1400	1		15.36	15.27	15.44	0.17	.0109	.0027				
	2	97.55	95.70	95.31	96.08	0.77	00804	.00548	2.46	0.587	1.67	.2840
	3	277.70	268.20	266.51	269.85	3.34	.01244	.0112	2.53	0.763	3.54	.4640
	4	533.50	528.20	523.26	532.31	9.05	.01710	.0163	2.52	1.18	5.23	.4430
	5	886.00	877.40	866.55	888.18	21.60	.0246	.0238	2.54	1.21	7.72	.6390
1350	1		15.52	15.43	15.61	0.176	.0113	.0039				
	2	98.30	96.53	95.88	97.03	1.15	.0120	.0097	2.49	0.657	3.01	.4580
	3	274.70	271.10	268.63	273.67	5.04	.0186	.0176	2.57	0.996	5.71	.573
	4	538.00	534.70	527.79	540.34	12.55	.0235	.0228	2.56	1.45	7.53	.5180
	5	893.00	889.70	880.05	901.96	21.91	.0246	.0239	2.58	1.63	8.02	.4920
	6	1342.50	1336.00	1313.37	1355.70	42.40	.0317	.0297	2.62	1.58	10.01	.6390
1300	2	99.00	97.54	96.43	98.28	1.85	.0189	.0169	2.53	0.876	5.37	.6140
	3	276.70	275.00	271.57	278.70	7.10	.0259	.0251	2.60	1.48	8.43	.5700
	4	542.50	542.80	535.16	550.80	15.60	.0287	.0281	2.60	1.93	9.63	.4980
	5	900.00	904.60	892.70	915.33	22.60	.0250	.0244	2.62	2.26	8.54	.3770
	6		1348.80	1331.91	1361.66	29.70	.0221	.0200				
1250	2	99.75	98.99	97.29	100.19	2.90	.0293	.0275	2.57	1.36	9.07	.6670
	3	278.70	280.60	276.53	285.14	8.60	.0307	.0299	2.64	2.40	10.60	.4410
	4	546.50	554.14	546.36	561.96	15.60	.0281	.0275	2.64	2.91	9.95	.3420
	5	906.20	924.70	916.55	933.53	17.00	.0184	.0178	2.66	3.39	6.61	.1950
	6		1345.00	1328.02	1358.70	30.70	.0228	.0207				
1200	2		105.13	104.12	106.31	2.19	.0208	.0186				
	3	280.60	286.50	282.96	290.26	7.30	.0255	.0247	2.69	3.46	9.25	.2670
	4	550.50	564.50	558.91	570.13	11.22	.0199	.0193	2.68	3.79	7.33	.1940
	5	913.00	938.30	931.45	944.91	13.47	.0144	.0138	2.70	3.99	5.31	.1330
	6	1370.00	1405.50	1396.41	1415.03	18.60	.0132	.0110	2.73	3.89	4.26	.1100
1150	2		105.13	103.92	106.26	2.35	.0223	.0203				
	3	282.60	291.10	288.86	293.67	4.81	.0165	.0158	2.72	4.19	6.17	.1470
	[illegible]	554.50	572.30	568.80	575.67	6.81	.0199	.0114	2.72	4.35	4.48	.1030
	[illegible]	919.50	948.90	944.11	953.11	9.00	.00948	.00896	2.74	4.37	3.54	.0810
	[illegible]	1378.50	1420.70	1415.63	1426.33	10.70	.00753	.00523	2.76	4.30	2.08	.0480
			105.28	104.56	106.30	1.75	.0166					
		[illegible]	294.84	293.43	296.17	2.75	.0093	.00856	2.76	4.71	3.45	.0730
		[illegible]	[illegible]	576.40	580.21	3.81	.0066	.00609	2.76	4.70	2.45	.0520
		[illegible]	[illegible]	955.57	960.71	5.14	.00537	.00487	2.77	4.69	1.97	.0420
		[illegible]	[illegible]	1431.02	1427.40	6.37	.00445	.00195	2.79	4.63	0.793	.0170

TABLE 25 (Continued)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M45

Experimental Measurements									Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1050	3	286.40	297.70	297.03	298.46	1.44	.00482	.0040	2.79	5.04	1.65	.0330
	4	560.70	583.60	582.51	584.69	2.18	.00373	.00325	2.78	5.13	1.34	.0260
	5	931.00	966.70	965.06	968.15	3.08	.00319	.0027	2.81	4.98	1.12	.0220
	6	1395.00	1446.30	1444.46	1448.44	4.02	.00275		2.83	4.89		
1000	2		106.96	106.77	107.19	0.42	.0039	.0027				
	3	288.00	300.00	299.57	0.90	.0030	.0021		2.82	5.28	8.81	.0170
	4	564.50	587.80	587.10	588.51	1.42	.0024	.0019	2.82	5.24	7.96	.0150
	5	936.00	973.30	972.29	974.47	2.18	.00224	.0018	2.84	5.16	7.55	.0150
	6	1402.50	1456.20	1454.76	1457.73	3.00	.0020					
900	2		108.31									
	3		303.70									
	4		594.80									
	5		984.80									
	6		1473.20									

TABLE 26

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M46

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1650	2	92.68	92.68									
	3	260.00	256.80	254.89	258.98	4.09	.0159	.0106	2.32	0.988	3.89	.3930
	4	510.70	506.20	501.48	511.30	9.82	.0194	.0156	2.33	1.167	3.87	.3315
	5	847.20	838.20	824.88	848.03	23.15	.0276	.0247			4.005	
	6	1268.70	1261.40	1251.88	1270.65	18.00	.0290	.0269				
1600	3	262.05	259.50	256.92	261.96	5.04	.0194	.0154	2.35	1.13	3.85	.3400
	4	514.90	512.60	506.36	519.18	12.83	.0250	.0224			5.730	
	5	860.70	849.90	829.81	862.29	32.49	.0382	.0362				
	6	1288.80	1286.70	1274.05	1301.24	27.20	.0412	.0398				
1550	3	264.20	262.30	258.80	265.46	6.66	.0254	.0222	2.39	1.28	5.69	.4430
	4	519.00	521.50	513.19	529.83	16.64	.0319	.0300	2.92	7.01	7.780	.4170
	5	860.70	865.10	840.97	882.30	41.30	.0478	.0465				
	7		1846.40	1819.27	1879.31	60.04	.0325	.0320				
1500	3	266.30	267.90	262.14	273.61	11.47	.0428	.0403	2.43	2.00	10.80	.5400
	4	523.10	531.30	522.52	539.49	16.97	.0319	.0305			8.530	
	5		882.80									
	6		1348.10	1324.57	1378.44	53.86	.0400	.0393				
1450	3	268.35	273.40	268.43	277.82	9.40	.0344	.0324	2.47	2.74	9.24	.3370
	4	517.20	540.80	533.65	548.70	15.10	.0278	.0267	2.387	1.52	7.970	.1920
	5		899.70	881.60	909.67	28.07	.0312	.0304				
	6		1364.30	1348.62	1385.43	36.81	.0270	.00191				
1400	2	96.38	101.29	100.15	102.30	2.15	.0212	.00191				
	3	270.44	278.50	274.12	282.36	8.24	.0296	.0282	2.51	3.42	8.44	.2470
	4	531.20	549.30	543.63	555.28	11.65	.0212	.0203	2.52	3.68	6.179	.1677
	5	880.60	917.10	924.62	903.42	21.20	.0231	.0224				
	6	1318.20	1377.20	1367.07	1388.29	21.22	.0154	.0149				
1350	2		101.40	100.45	102.29	1.84	.0182	.0164				
	3	272.50	283.20	280.06	285.84	5.78	.0204	.0193	2.54	4.03	6.04	.1490
	4	535.10	556.50	552.46	560.51	8.05	.0145	.0138	2.55	4.09	4.33	.1060
	5	887.20	926.60	920.39	932.05	11.67	.0126	.0120	2.57	4.38	3.84	.0880
	6		1391.00	1383.50	1398.01	14.51	.0104	.0100				
1300	2		102.25	101.68	102.97	1.29	.0127	.0112				
	3	274.54	286.70	284.77	288.58	3.81	.0133	.0124	2.58	4.40	3.99	.0906
	4	539.20	562.50	564.97	559.94	5.03	.00894	.00844	2.59	4.35	2.72	.0624
	5	893.90	937.10	933.01	941.18	8.17	.00872	.00822	2.61	4.69	2.70	.0575
	6		1404.30	1398.31	1409.05	10.64	.00758	.00712				
	7		1962.70	1957.10	1968.40	11.33	.00577	.00537				
1250	2	98.69	103.30	102.82	103.91	1.10	.0106	.0094				
	3	276.60	290.00	288.87	291.20	2.33	.00803	.0073	2.62	4.75	2.42	.0510
	4	543.00	568.10	566.60	569.77	3.17	.00557	.00508	2.63	4.60	1.67	.0360
	5	900.50	946.40	944.11	949.31	5.20	.00549	.0050	2.64	4.93	1.68	.0341
	6	1347.80	1417.60	1420.62	1413.65	6.97	.00492	.00444				
	7		1980.60	1976.56	1984.13	7.57	.00382	.00332				

TABLE 26 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M46

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1200	2		104.39	104.01	104.78	0.77	.00741	.00641				
	3	278.60	292.80	292.09	293.48	1.39	.00474	.00417	2.66	4.96	1.41	.0284
	4	546.80	573.10	572.08	574.09	2.00	.00350	.00311	2.66	4.78	1.04	.0218
	5	907.00	954.40	952.74	956.02	3.28	.00344	.00303	2.68	5.09	1.04	.0204
	6		1429.60	1426.94	1431.48	4.53	.00317	.00268				
	7		1996.10	1993.98	1998.64	4.66	.00234	.00180				
1100	2		106.15	106.00	106.33	0.33	.00312	.00212				
	3	282.50	297.50	297.23	297.77	0.54	.00182	.00122	2.73	5.24	4.26	.0081
	4	554.60	581.84	581.33	582.28	0.95	.00163	.00133	2.74	4.99	4.60	.0092
	5	919.80	968.90	968.05	969.74	1.69	.00174	.00137	2.76	5.31	4.84	.0091
	6		1450.80	1449.88	1451.93	2.04	.00141	.00083				
	7		2025.70	2024.09	2026.55	2.46	.00122	.0006				
76	2		116.26									
	3		325.41									
	4		635.60									
	5		1057.90									
	6											
	7											

TABLE 27

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M6

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-5}$	η_D
1400	1	14.76	14.12	14.04	14.20	0.162	.01144	.00424				
	2	91.38	89.25	89.02	89.49	0.466	.00522	.00262	2.43	0.30	0.840	.2730
	3	255.90	250.20	249.56	250.91	1.35	.00538	.00438	2.52	0.376	1.409	.3750
	4		490.50	488.88	492.37	3.49	.00715	.00582	2.52	.0492	2.695	.5470
	5	830.80	813.74	809.78	817.19	7.41	.00911	.00830	2.53	0.548	3.704	.6720
	6	1243.00	1218.50	1211.39	1225.99	14.60	.01194	.01130				
1350	1		14.21	14.40	14.28	0.141	.00995	.00315	2.47	0.265		.5930
	2	92.10	89.95	89.58	90.21	0.63	.00707	.0050	2.55	0.390	1.625	.6200
	3	257.80	252.09	251.12	153.13	2.00	.00797	.00715	2.54	0.389	2.416	.6181
	4		531.90	527.98	534.62	6.63	.0125	.01105				
	5		819.90	813.87	825.49	11.62	.01418	.0134				
	6		1230.30	1219.20	1240.70	21.50	.01744	.0170				
1300	1	14.76	14.51	14.45	14.58	0.132	.00914	.00314	2.59	5.68	1.048	.1800
	2		90.65	90.17	91.02	0.85	.00937	.00687				
	3	259.60	254.60	252.95	256.03	3.08	.0121	.0114	2.59	5.91	4.008	.6780
	4		499.90	495.98	505.15	9.17	.0183	.0170				
	5	843.80	829.30	817.33	837.52	20.19	.0244	.0237	2.60	7.37	7.782	1.0540
	6	1261.00	1246.80	1229.71	1262.80	33.10	.0265	.0260	2.60	1.15	8.996	.7800
1250	1		14.68	14.63	14.78	0.149	.01016	.00416				
	2	73.45	91.46	90.38	91.98	1.60	.0175	.0151	2.55	4.74	5.065	1.034
	3	261.40	257.71	254.98	260.42	5.43	.02109	.0204	2.63	9.57	7.016	.7330
	4		535.60	531.29	538.74	7.44	.0139	.0125				
	5	849.70	844.00	821.42	854.70	33.28	.0394	.0387	2.64	1.49	13.704	.9210
	6	1319.00	1272.30	1251.20	1294.20	43.00	.0338	.0334	3.10	2.71	14.596	.5395
1200	1		14.78	14.68	14.89	0.20	.01375	.00835				
	2		98.30	97.76	98.99	1.23	.0125	.0102				
	3		262.30	258.02	266.65	8.63	.0329	.0323				
	4		535.30	530.87	539.75	8.90	.01663	.0153				
	5	853.00	861.40	838.15	873.97	35.82	.0416	.0418	2.66	2.08	1.609	.7710 (1)
	6		1298.90	1278.12	1317.90	39.80	.0306	.0301				
1150	1	15.14	14.80	14.65	14.95	0.304	.0206	.0154	2.71	3.91	5.370	.1370
	2		93.85	90.31	95.17	4.90	.0517	.0492				
	3	266.10	268.56	263.74	272.996	9.30	.0345	.0340	2.72	4.42	13.509	.3230
	4		538.07	527.82	541.89	14.07	.0262	.0250				
	5	860.40	877.90	866.10	887.47	21.37	.0243	.0236	2.71	3.56	9.452	.2650
	6	1353.20	1319.60	1307.19	1332.80	25.60	.01941	.0188	3.02	6.59	8.139	.1240
1100	1	15.19	15.38	15.14	15.65	0.505	.03281	.0279	2.72	2.97	10.633	.3640
	2		97.37	97.00	97.82	0.816	.01648	.01458				
	3	264.60	274.50	271.04	277.87	6.83	.02488	.0242	2.69	3.16	9.243	.2920
	4		527.29	524.74	530.42	5.71	.01082	.00964				
	5	865.40	894.90	888.02	901.47	13.45	.01503	.01410	2.74	4.63	5.273	.1210
	6	1369.00	1330.30	1330.50	1345.90	15.40	.0115	.0111	3.02	8.02	5.508	.00687

TABLE 27 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M6

		EXPERIMENTAL MEASUREMENTS							MATERIAL PROPERTIES			
TEMP. °F	MODE	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1050	1	15.22	15.63	15.35	15.91	0.568	.0363	.0316	2.74	3.64	13.163	.3610 (2)
	3	267.60	278.29	276.21	280.32	4.11	.0148	.0142	2.75	5.24	5.097	.0972
	4		546.60	544.40	548.10	3.70	.00677	.00561				
	5	870.10	904.60	900.41	908.47	8.06	.00891	.00811	2.77	5.32	3.514	.0660
	6	1308.70	1351.50	1346.40	1356.30	9.86	.0073	.0070	2.80	4.67	2.975	.0633
850	1		16.40	16.34	16.44	0.107	.00655	.00285				
	2		102.99	102.85	103.13	0.287	.00279	.00188				
	3		288.13	287.79	288.51	0.714	.00248	.00204				
	4		565.20	564.65	565.99	1.34	.00237	.00146				
	5		933.40	932.44	934.58	2.139	.0023	.00188				
	6		1392.40	1391.00	1393.70	2.71	.00195	.00175				
600	1		16.63									
	2		105.64									
	3		295.70	295.41	295.95	0.542	.00183	.00143				

(1) $E_D + \eta_D$ @ 1220 °F

(2) $E_D + \eta_D$ @ 1070 °F

TABLE 28

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M7

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-5}$	E_{DI} PSI $\times 10^{-5}$	η_D
1450	1		13.65	13.53	13.78	0.25	.0182	.0057				
	2	87.50	85.95	86.29	85.76	0.53	.0062	.0034	2.48	0.663		.1700
	3	245.20	240.90	240.36	241.49	1.13	.0047	.00342	2.57	0.916	1.081	.2010
	4	481.00	475.80	474.50	477.55	3.06	.00643	.00533	2.57	0.109	1.710	.1090
	5	785.80	784.20	782.23	788.84	4.62	.00589	.0049	2.29	1.559	1.564	.1003
	6	1176.90	1173.80	1170.69	1176.89	6.20	.00528	.0046	2.31	1.539	1.479	.0961
1400	1	14.04	14.13	14.11	14.26	0.153	.0108	.00994				
	2	88.87	87.43	87.21	87.63	0.43	.0049	.0026	2.56	0.749		.1190
	3	248.90	244.70	243.96	245.33	1.56	.00639	.00565	2.65	0.755		.2670
	4	487.70	481.37	479.73	482.91	3.17	.00659	.0057	2.64	0.103		.1950
	5		797.00	793.21	800.32	7.11	.00892	.00337				
	6		1192.60	1187.37	1199.04	11.70	.00979	.00929				
1300	1	14.18	14.23	14.20	14.35	0.145	.0102	.0974				
	2	89.53	88.16	88.05	88.31	0.257	.00568	.00358				
	3	250.70	246.96	246.05	247.86	1.81	.00731	.00664	2.69	0.892		.3690
	4	488.30	486.00	483.47	488.26	4.80	.00986	.00906	2.41	1.470	3.028	.2054
	5	815.30	804.80	799.11	810.18	11.10	.0138	.0130	2.70	1.050	4.351	.3080
	6	1219.70	1204.30	1193.32	1214.48	21.20	.0176	.0172	2.46	1.250	5.788	.3170
1250	1	14.38	14.15	14.03	14.20	0.171	.0121	.0047				.1018
	2	90.20	88.93	88.64	89.39	0.75	.00846	.0065	2.64	0.917	2.189	.2520
	3	252.50	249.40	248.10	251.01	2.91	.0117	.0111	2.73	1.09	3.745	.5010
	4	491.60	491.20	487.30	495.54	8.21	.0167	.0160	2.69	1.93	5.440	.2150
	5	821.00	814.70	805.61	821.56	15.95	.0196	.0188	2.74	1.38	6.437	.5120
	6	1228.70	1220.00	1204.40	1234.70	30.30	.0249	.0245	2.75	1.48	8.431	.4850
1200	1	14.35	14.24	14.13	14.26	0.129	.00906	.00186	2.43	1.71	0.633	.0371
	2	90.85	89.63	89.18	90.49	1.31	.0146	.0128	2.49	1.96	4.506	.2303
	3	254.30	251.83	249.83	254.26	4.43	.0176	.0170	2.76	1.29		.6430
	4	498.55	497.30	491.71	502.89	11.20	.0225	.0219	2.56	1.11	7.614	.6889
	5	826.80	824.70	811.29	833.96	22.70	.0275	.0267	2.57	1.11	9.342	.8399
	6	1237.70	1239.90	1217.60	1256.10	38.50	.03108	.0306	2.63	1.00	10.866	.4720
1150	1	14.51	14.40	14.32	14.51	0.187	.0130	.0063				
	2	91.50	91.00					.0210	2.71	1.55		.5060
	3	256.10	256.00	253.34	259.65	6.40	.0250	.0243	2.80	2.05		.5600
	4	502.00	506.10	498.00	513.00	15.00	.0297	.0291	2.80	2.71	10.454	.3600
	5	829.60	840.30	826.58	849.40	22.80	.0272	.0264	2.80	2.33	9.593	.4600 (1)
	6	1242.10	1264.10	1280.75	1245.49	34.80	.0275	.0270	2.58	3.01	10.249	.4050 (2)
1100	1	14.98	14.55	14.69	14.42	0.273	.0188	.0128	2.58	1.23	4.511	.3680
	2	92.15	94.80	95.96	94.02	1.54	.0162	.0148	2.75	2.76	5.647	.3940
	3	257.70	260.90	264.96	257.82	7.10	.0274	.0264	2.84	3.14	9.661	.3170
	4	503.60	515.40	521.24	508.72	12.50	.0243	.0237	2.82	3.24	8.849	.3420 (3)
	5	837.80	854.80	862.96	843.88	19.10	.0223	.0216	2.86	3.82	8.133	.2170
	6	1254.80	1284.00	1295.20	1272.30	22.90	.01784	.0173	2.79	1.40	6.616	.1790

TABLE 28 (CONTINUED)

EXPERIMENTAL MEASUREMENTS AND MATERIAL PROPERTIES FOR COATING M7

		Experimental Measurements							Material Properties			
Temp. °F	Mode	F_M Hz	F_C Hz	F_L Hz	F_R Hz	ΔF	η_S	η_C	E_M PSI $\times 10^{-7}$	E_{DR} PSI $\times 10^{-6}$	E_{DI} PSI $\times 10^{-6}$	η_D
1050	1	15.12	14.74	14.98	14.48	0.49	.0334	.0278	2.79	1.40	9.991	.4740
	2	92.75	94.00	95.10	93.40	1.70	.0181	.0169	2.79	3.94	6.317	.2780
	3	259.40	266.60	269.54	264.19	5.30	.0200	.0194	2.88	4.34	7.099	.1390
	4	508.60	523.90	527.90	520.50	7.40	.0141	.0135	2.87	4.65	5.727	.1850
	5	843.00	868.40	873.13	862.89	10.20	.0118	.0111	2.89	4.62	4.331	.1090
	6	1262.80	1302.40	1294.30	1294.30	14.60	.0112	.0106	2.90	4.78	4.186	.0937
1000	1	15.19	15.09	15.36	14.83	0.533	.0353	.0300	2.82	7.19	11.245	
	2	93.34	96.22	97.08	95.32	1.76	.0183	.0172	2.82	4.78	6.755	.1590
	3	261.07	269.50	271.30	268.07	3.23	.0120	.0110	2.91	4.94	4.332	.1010
	4	531.90	529.50	531.91	527.23	4.68	.00884	.0082	2.86	1.76	3.253	.1851
	5	848.75	877.70	881.45	874.58	6.86	.00782	.0072	2.88	1.79	2.873	.1606
	6	1270.70	1315.10	1319.40	1310.60	8.82	.00671	.0060	2.91	1.88	2.420	.0532
950	1	15.71	15.51	15.70	15.33	0.373	.02404	.0186	2.95	1.19	7.430	.6228
	2	93.88	97.57	97.33	97.90	0.562	.0112	.0102	2.86	5.43	4.166	.0850
	3	262.50	272.20	273.39	271.41	1.98	.00728	.0067	2.95	5.36	2.698	.0414
	4	514.80	534.20	535.70	532.79	2.91	.00545	.0048				
	5	850.60	884.80	886.84	882.46	4.38	.00495	.00447	2.94	5.31		.0490 (4)
	6	1277.80	1325.70	1328.90	1322.80	6.15	.00464	.00404	2.97	5.47		.0342
800	1		16.03	16.08	15.98	0.104	.00649	.0015				
	2		99.87	100.06	99.76	0.30	.0030	.0021				
	3		278.40	278.76	278.09	0.667	.00239	≈.002				
	4		545.90	546.30	545.08	1.22	.00224	.0014				
	5		903.90	904.90	902.69	2.20	.00244	.00201				
	6		1354.10	1357.70	1352.60	3.12	.0023	.00196				

(1) $E_D + \eta_D$ @ 1175 °F

(2) $E_D + \eta_D$ @ 1175 °F

(3) $E_D + \eta_D$ @ 1125 °F

(4) $E_D + \eta_D$ @ 975 °F

TABLE 29

VALUES AND TEMPERATURES OF MAXIMUM LOSS MODULUS AND LOSS FACTOR OF TEST MATRIX COATINGS

Specimen Number	Additions Al_2O_3 (Wt. %)	Na_2O (Wt. %)	Co_2O_3 (Wt. %)	Maximum η_D	Maximum $E_D'' \times 10^{-9} N/M^2$	Temperature E''_{Dmax} °C 100 Hz	1000 Hz	Temperature η_{Dmax} °C 100 Hz	1000 Hz
M30	0	0	0	0.64	9.0	620	670	650	720
M1	7.5	0	0	0.48	7.6	710	765	750	805
M36	15.0	0	0	0.1	2.1	850	920	860	960
M2	0	3.0	0	0.3	7.6	615	690	615	690
M19	0	6.0	0	0.42	8.3	565	620	590	960
M17	7.5	3.0	0	0.6	9.0	670	715	700	770
M29	15.0	3.0	0	0.3	4.1	850	930	875	990
M49	7.5	6.0	0	0.42	5.0	730	810	690	750
M32	15.0	6.0	0	0.47	4.8	735	810	775	860
M26	0	0	1.0	0.6	7.6	610	670	650	725
M12	7.5	0	1.0	0.36	6.9	730	790	750	860
M21	15.0	0	1.0	0.22	2.9	820	915	850	1000
M35	7.5	3.0	1.0	0.6	6.2	690	745	720	--
M24	15.0	3.0	1.0	0.58	6.8	750	820	790	910
M11	7.5	6.0	1.0	0.35	9.0	620	665	680	740
M22	15.0	6.0	1.0	0.57	6.0	720	800	770	860
M14	0	3.0	1.0	0.64	6.9	560	650	620	670
M48	0	6.0	1.0	0.64	7.6	595	620	650	815

TABLE 29 (CONTINUED)

VALUES AND TEMPERATURES OF MAXIMUM LOSS MODULUS AND LOSS FACTOR OF TEST MATRIX COATINGS

Specimen Number	Additions Al_2O_3 (Wt. %)	Na_2O (Wt. %)	Co_2O_3 (Wt. %)	Maximum η_D	Maximum $E_D'' \times 10^{-9}$ N/M^2	Temperature E''_{Dmax} °C 100 Hz	1000 Hz	Temperature η_{Dmax} °C 100 Hz	1000 Hz
M5	0	0	2.0	1.05	7.2	620	665	675	730
M27	7.5	0	2.0	0.4	7.6	730	815	770	860
M41	15.0	0	2.0	0.18	3.0	840	960	870	--
M31	7.5	3.0	2.0	0.9	7.6	690	745	730	--
M4	15.0	3.0	2.0	0.27	6.2	800	885	845	960
M45	7.5	6.0	2.0	0.6	7.3	650	710	680	760
M46	15.0	6.0	2.0	0.44	5.5	760	845	780	870
M6	0	3.0	2.0	0.85	11.0	555	665	660	720
M7	0	6.0	2.0	0.56	7.2	585	625	620	670

TABLE 30

GLASS TRANSITION TEMPERATURES (Tg) AND ACTIVATION ENERGIES (ΔH) OF TEST MATRIX GLASS COMPOSITIONS

Specimen Number	Tg (°F)	ΔH (K. Cal. $mole^{-1}$)
M30	805	60.0
M1	990	91.5
M36	1113	63.7
M2	826	52.0
M19	767	52.5
M17	915	66.1
M29	1081	57.5
M49	887	74.9
M32	1054	63.7
M26	825	56.0
M12	925	48.0
M21	1224	43.5
M35	870	-
M24	921	47.8
M11	913	73.4
M22	952	59.9
M14	837	76.8
M48	789	84.0
M5	852	78.8
M27	900	59.9
M41	1005	-
M31	871	-
M4	1094	54.7
M45	916	56.1
M46	1048	61.0
M6	836	70.4
M7	807	76.8

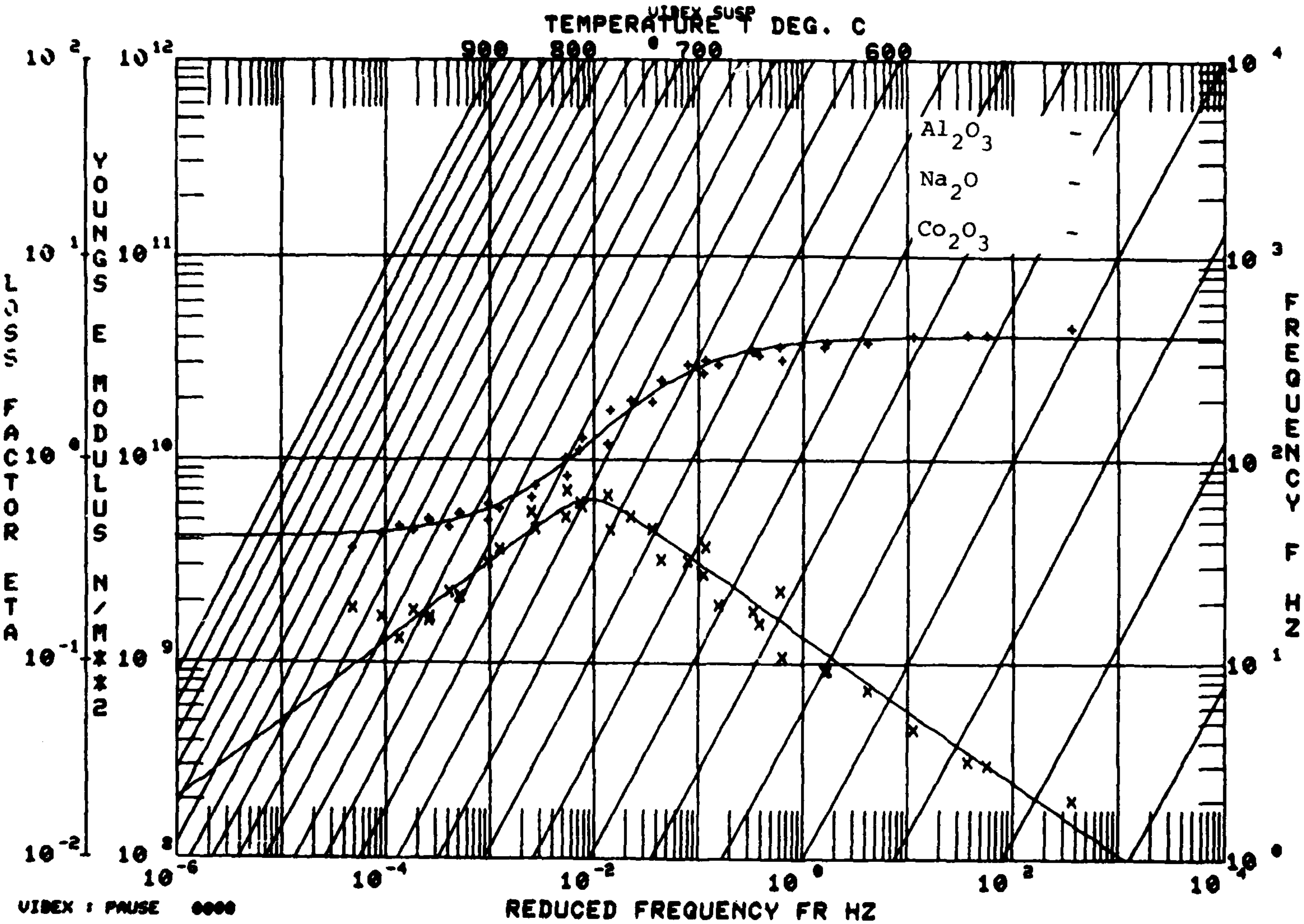

Figure 11. Specimen M30 reduced frequency and temperature nomograph.

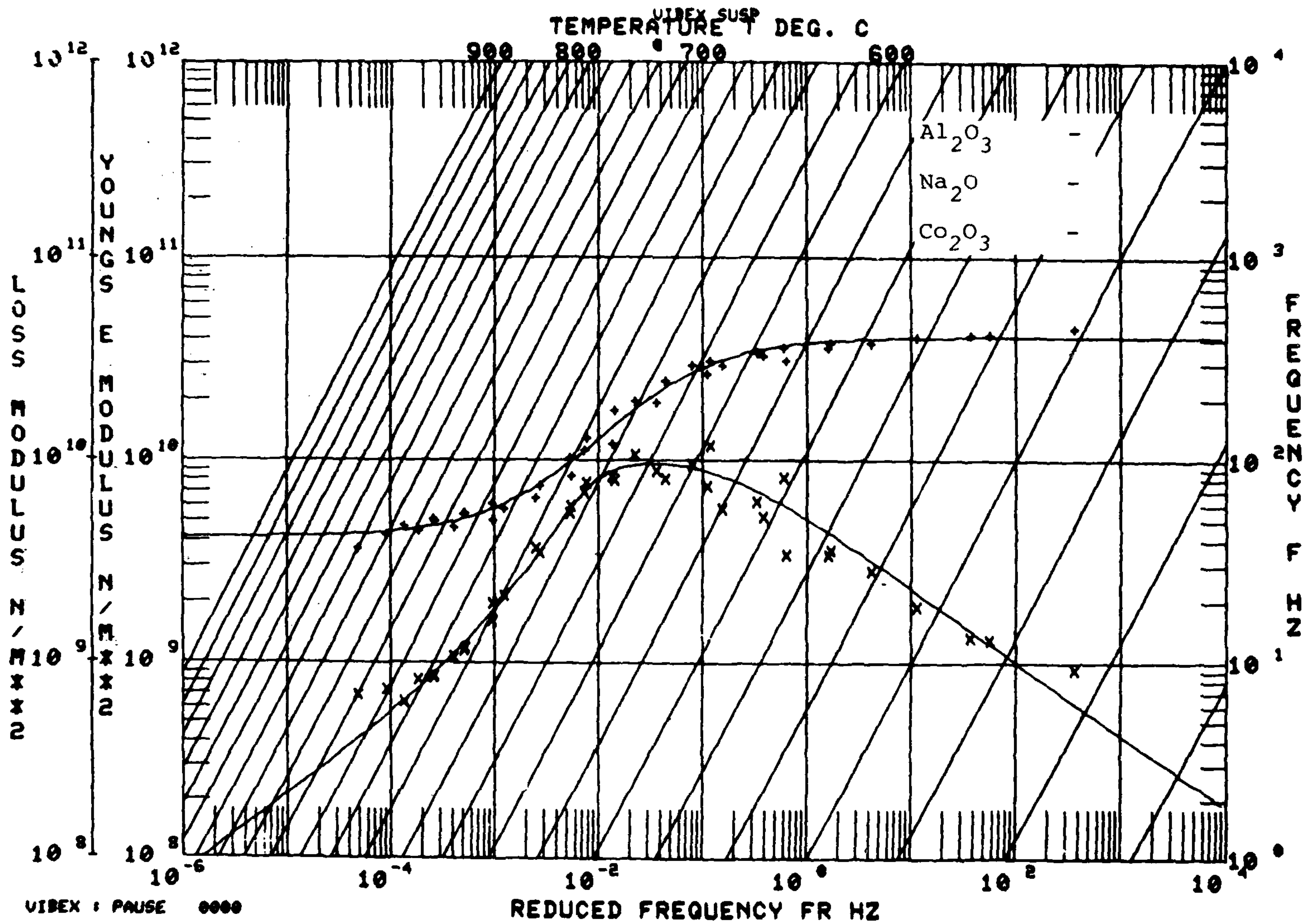

Figure 12. Specimen M30 reduced frequency and temperature nomograph.

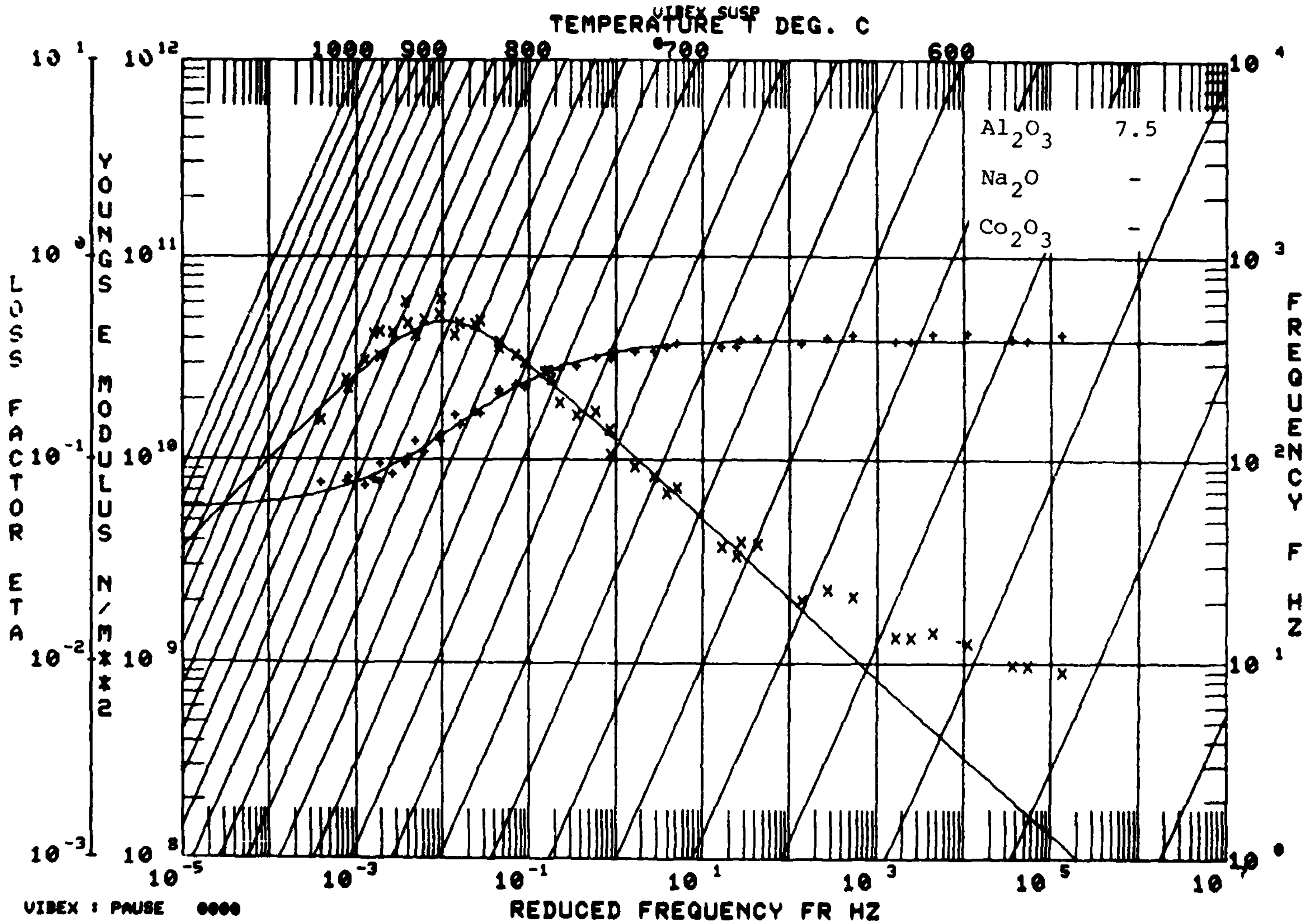

Figure 13. Specimen M1 reduced frequency and temperature nomograph.

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A STUDY TO DETERMINE THE EFFECT OF GLASS COMPOSITIONAL VARIATIO--ETC(U)
MAY 80 G A GRAVES, C CANNON, B KUMAR F33615-76-C-5137
UNCLASSIFIED UDR-TR-80-27 AFWAL-TR-80-4061 NL

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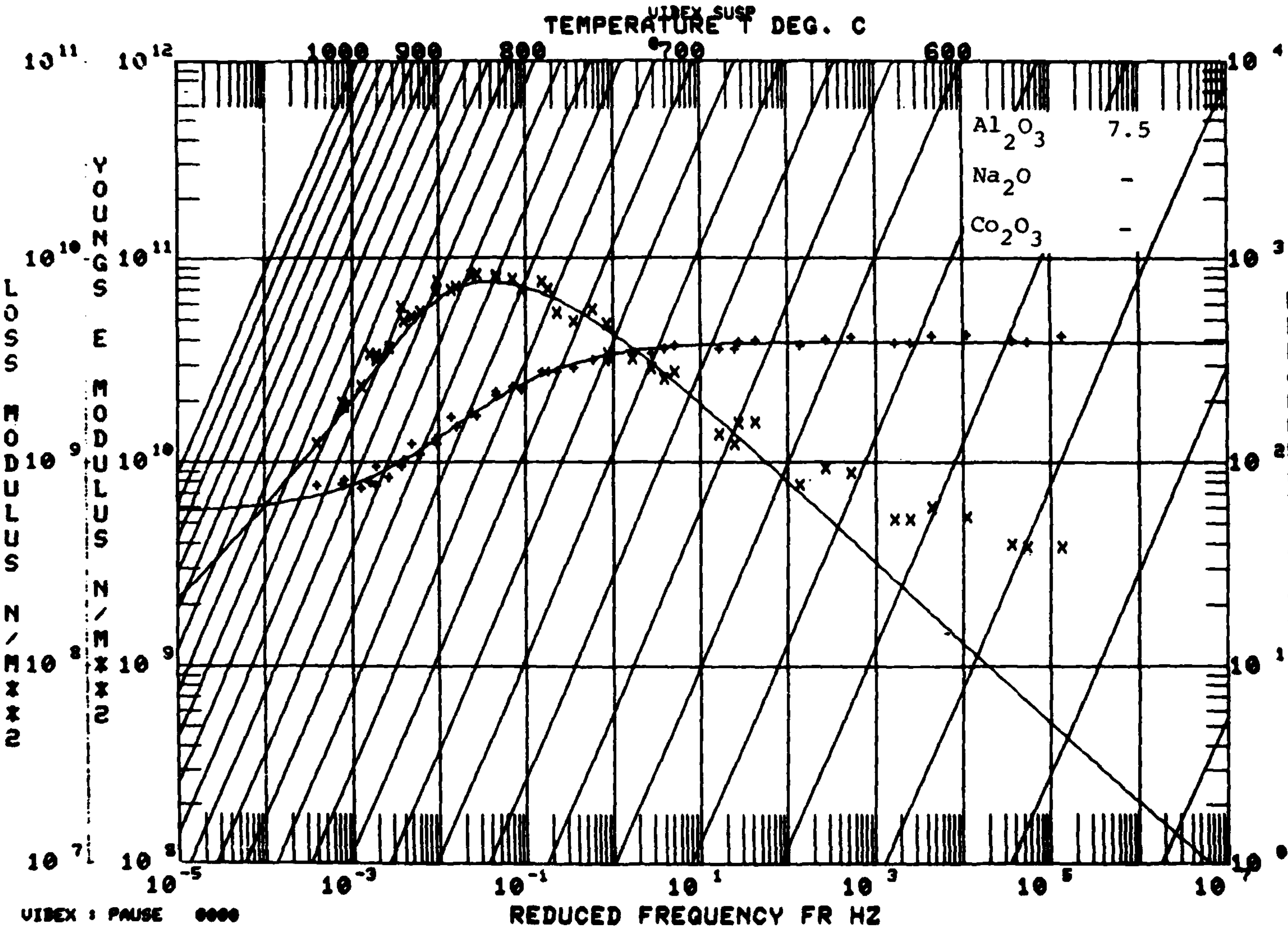

Figure 14. Specimen M1 reduced frequency and temperature nomograph.

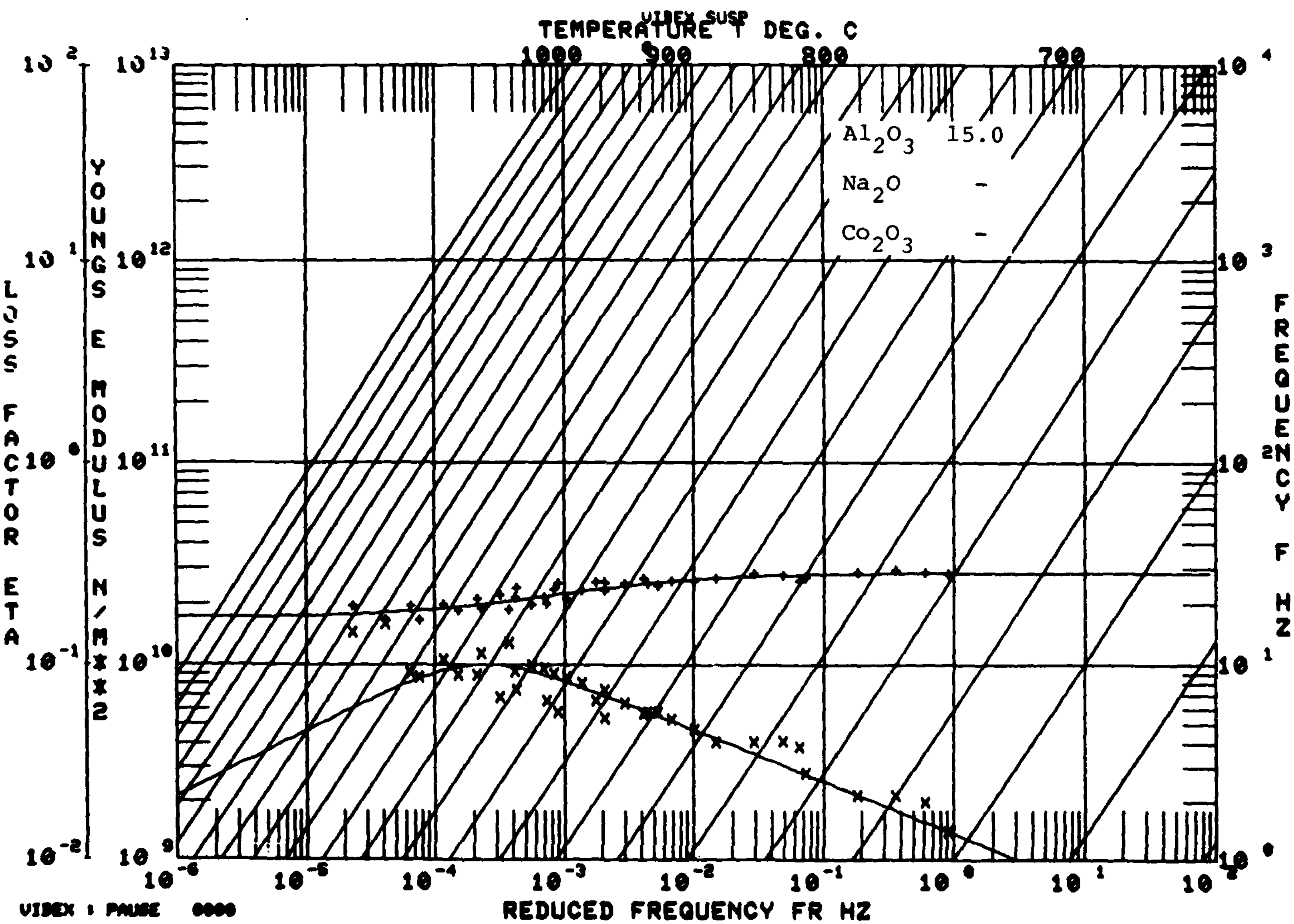

Figure 15. Specimen M36 reduced frequency and temperature nomograph.

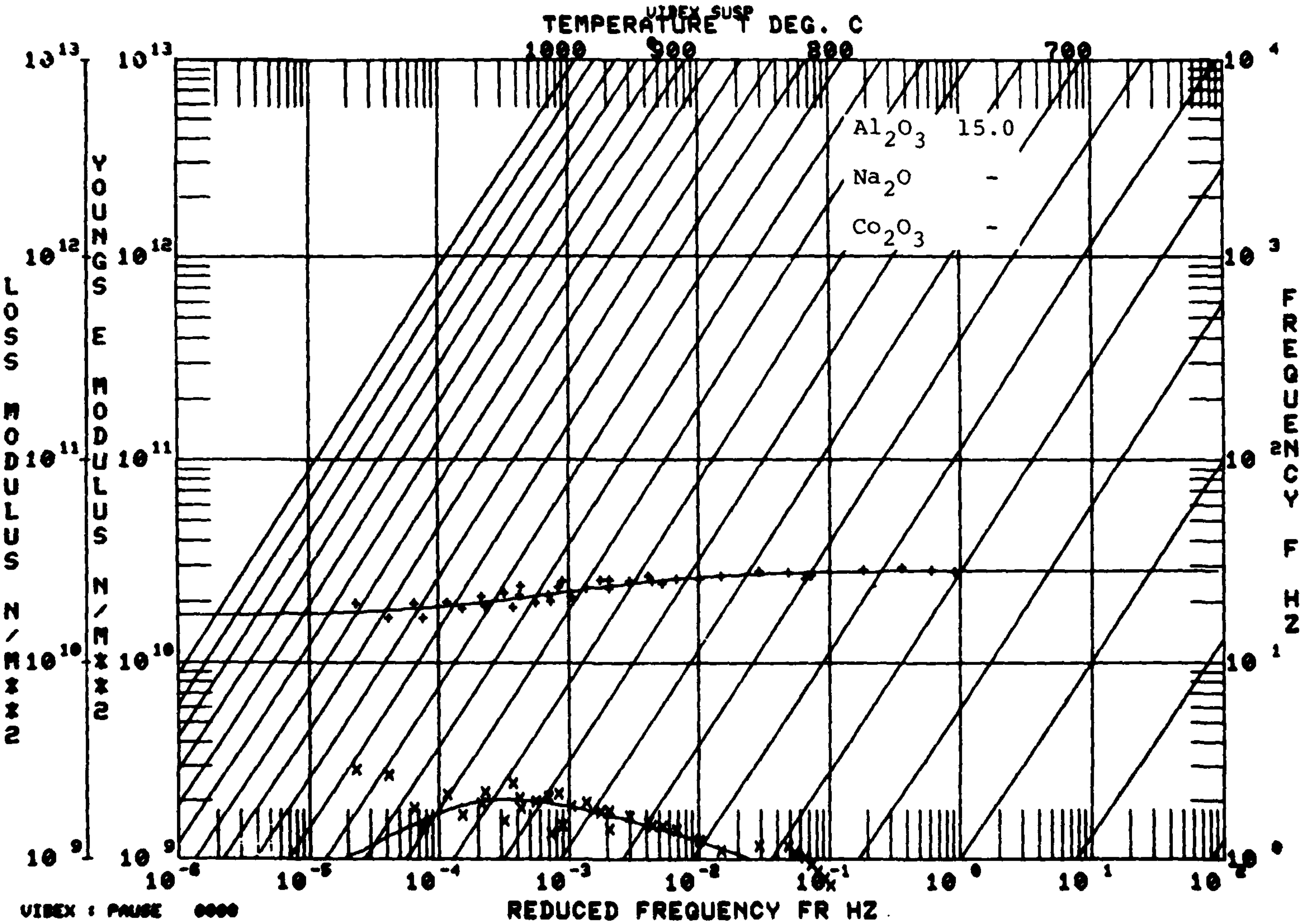

Figure 16. Specimen M36 reduced frequency and temperature nomograph.

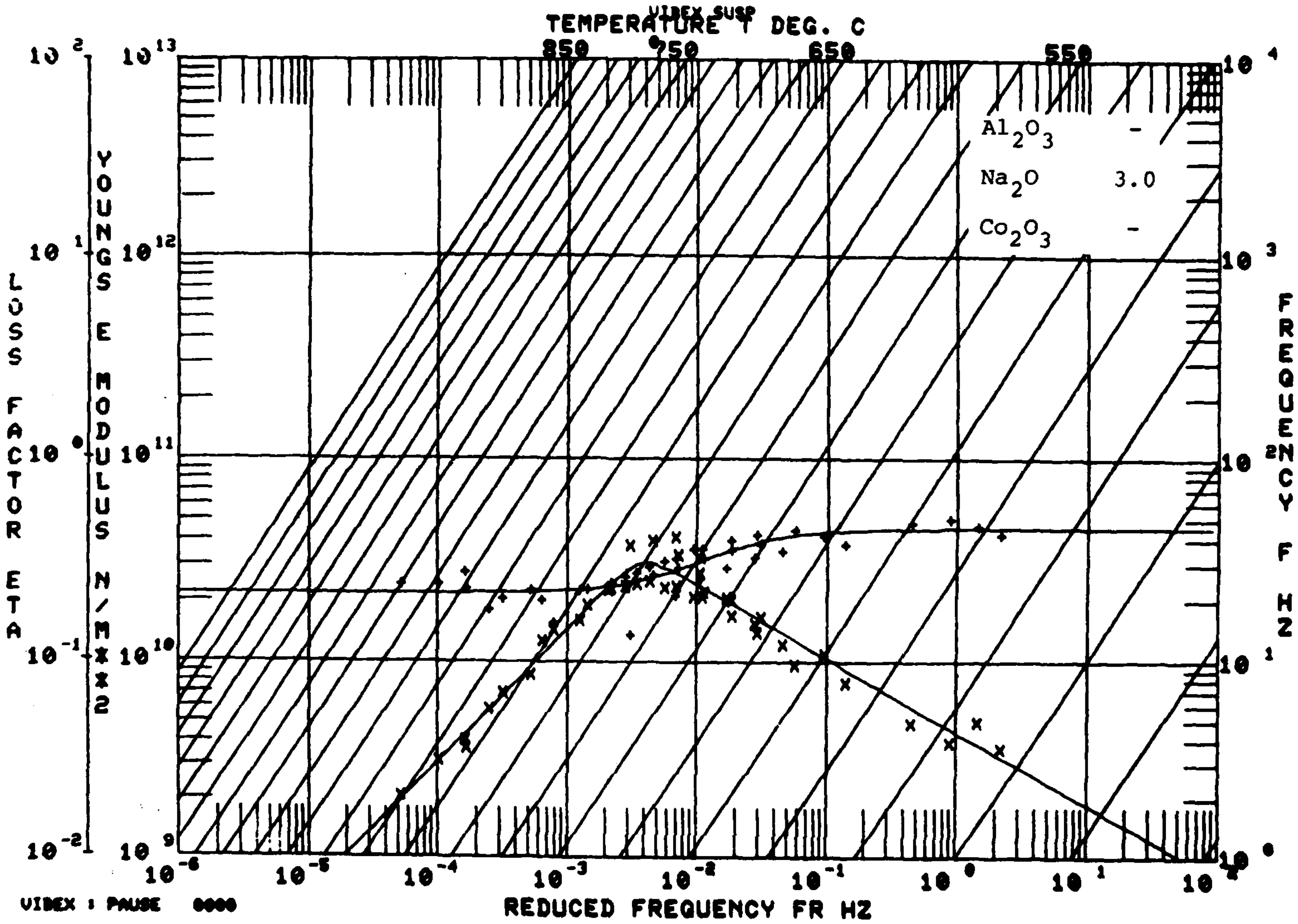

Figure 17. Specimen M2 reduced frequency and temperature nomograph.

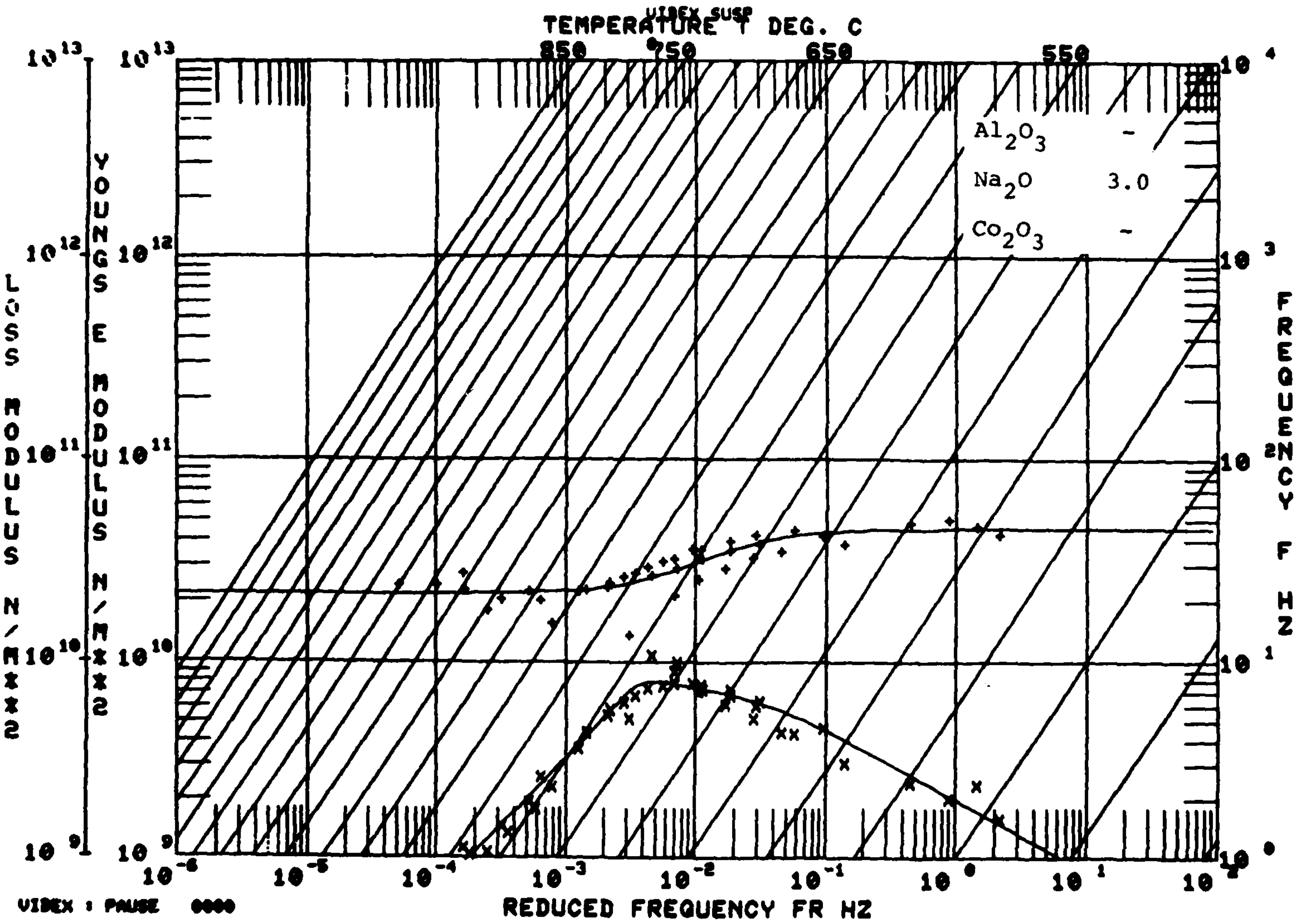

Figure 18. Specimen M2 reduced frequency and temperature nomograph.

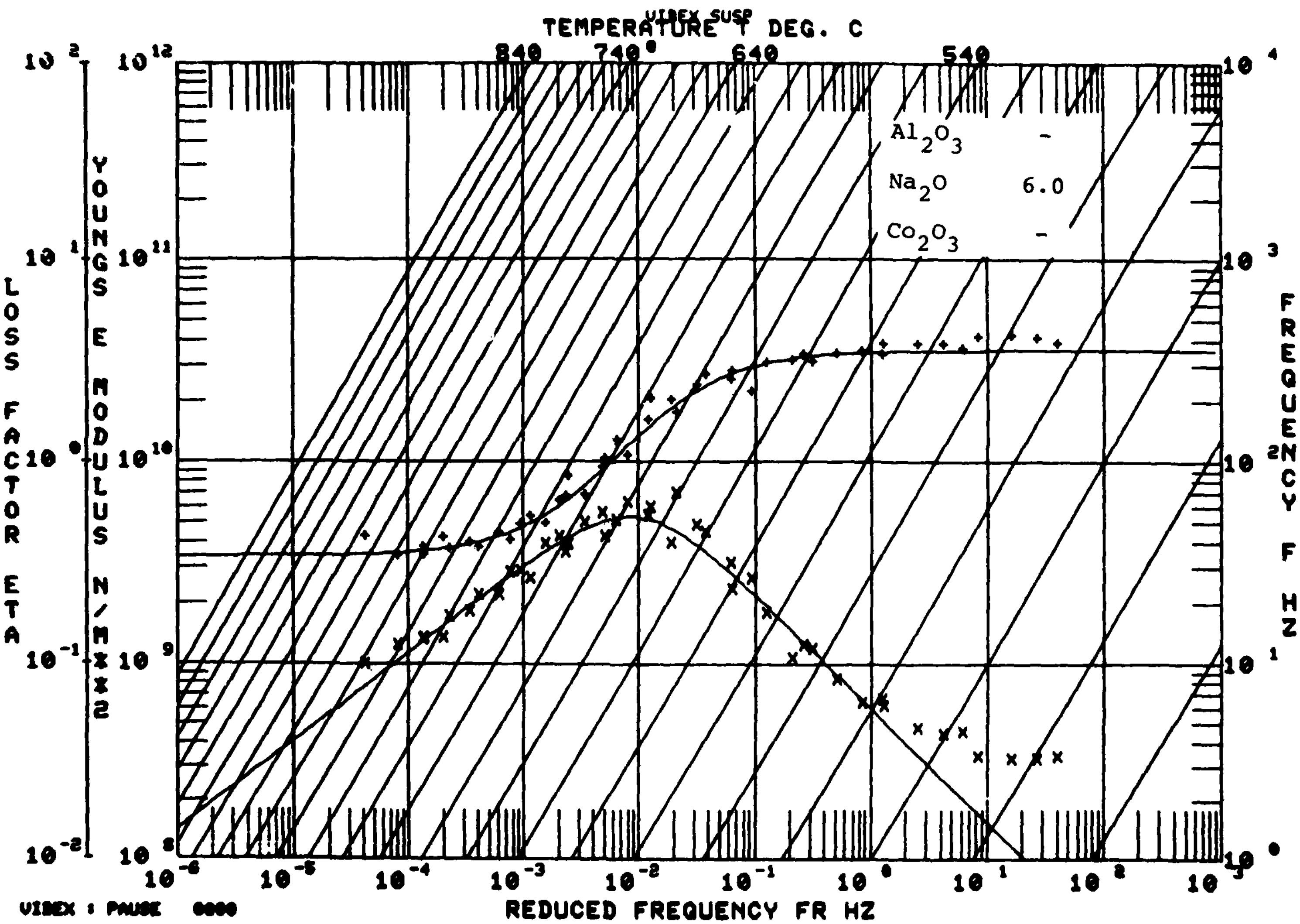

Figure 19. Specimen M19 reduced frequency and temperature nomograph.

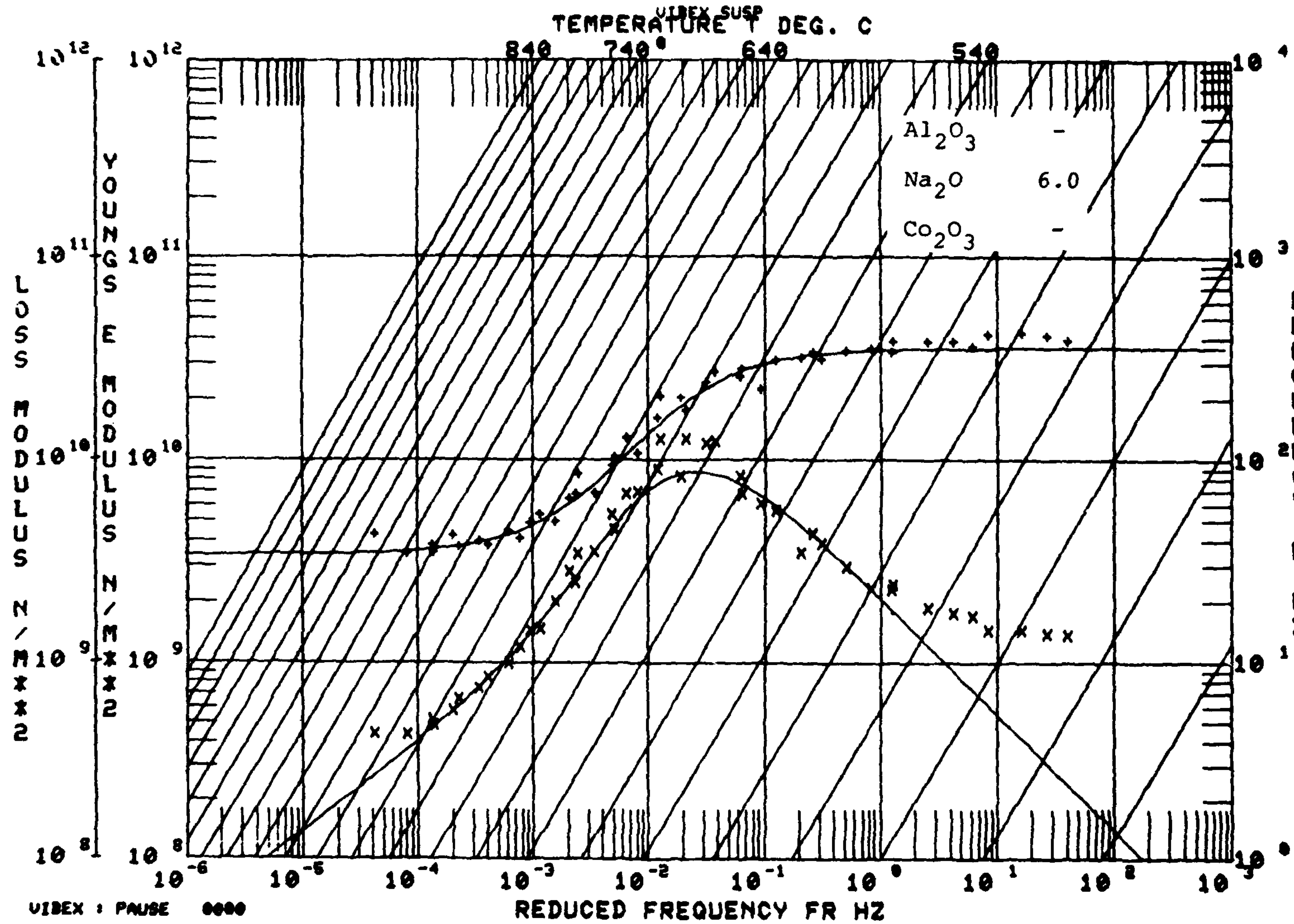

Figure 20. Specimen M19 reduced frequency and temperature nomograph.

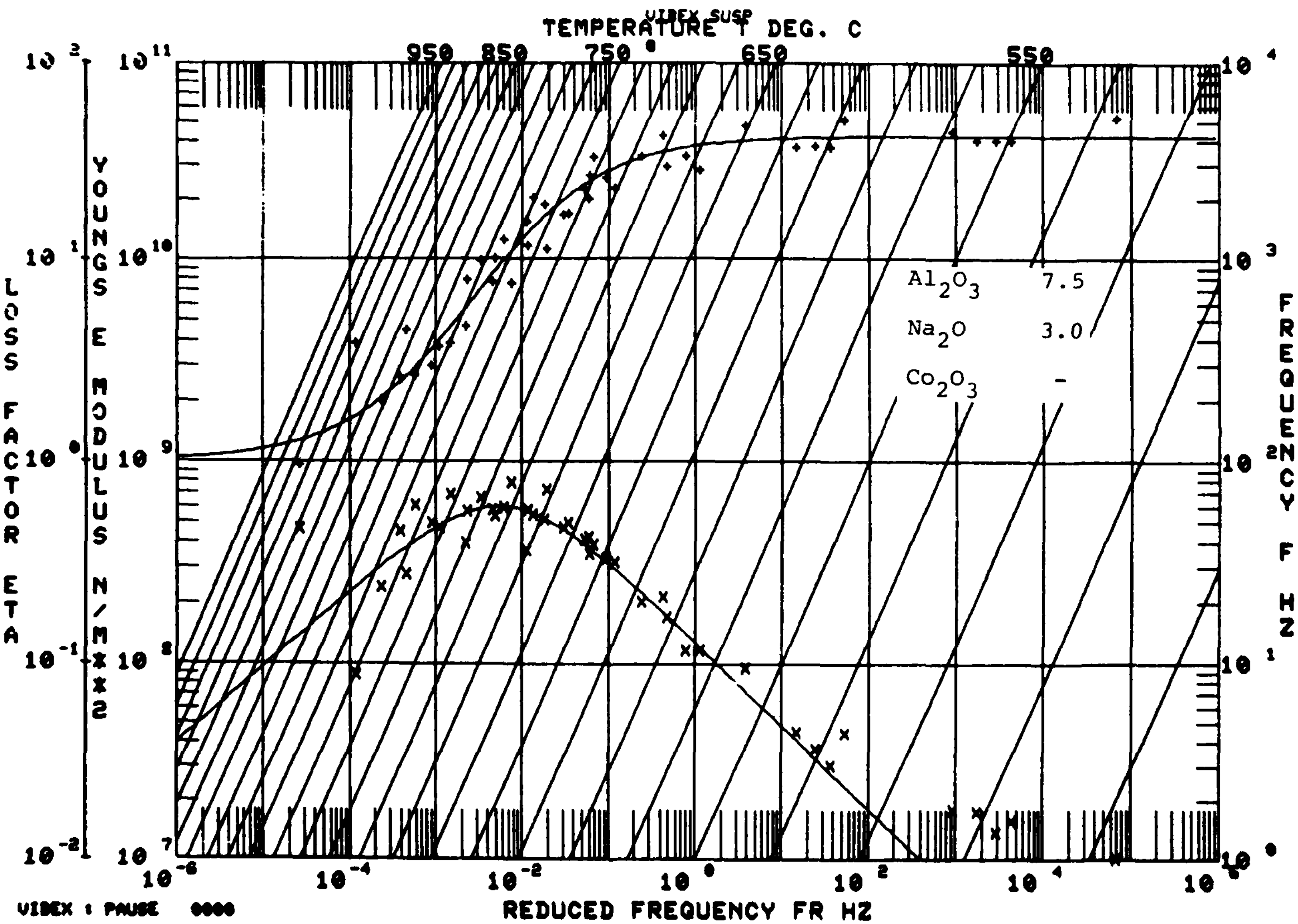

Figure 21. Specimen M17 reduced frequency and temperature nomograph.

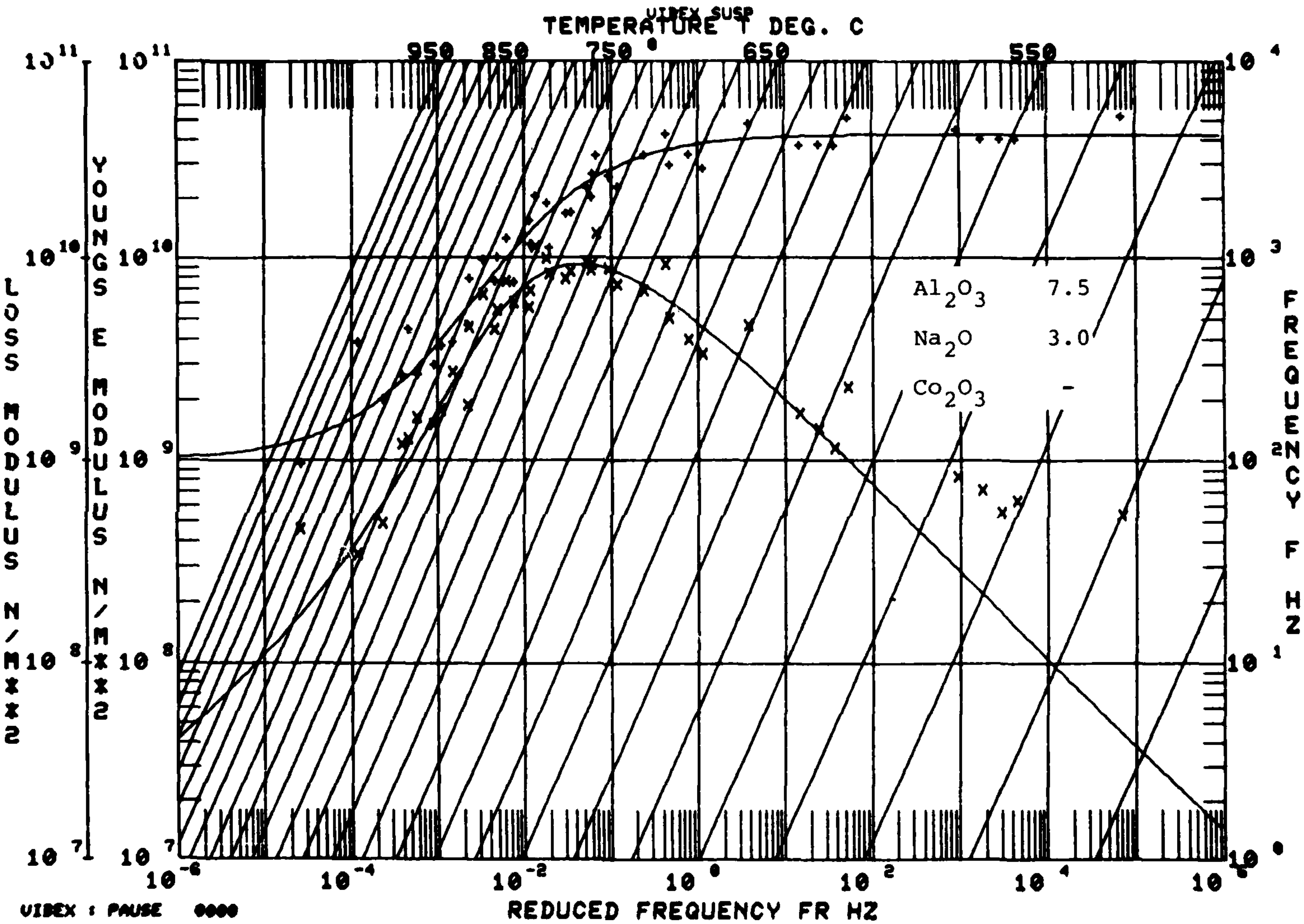

Figure 22. Specimen M17 reduced frequency and temperature nomograph.

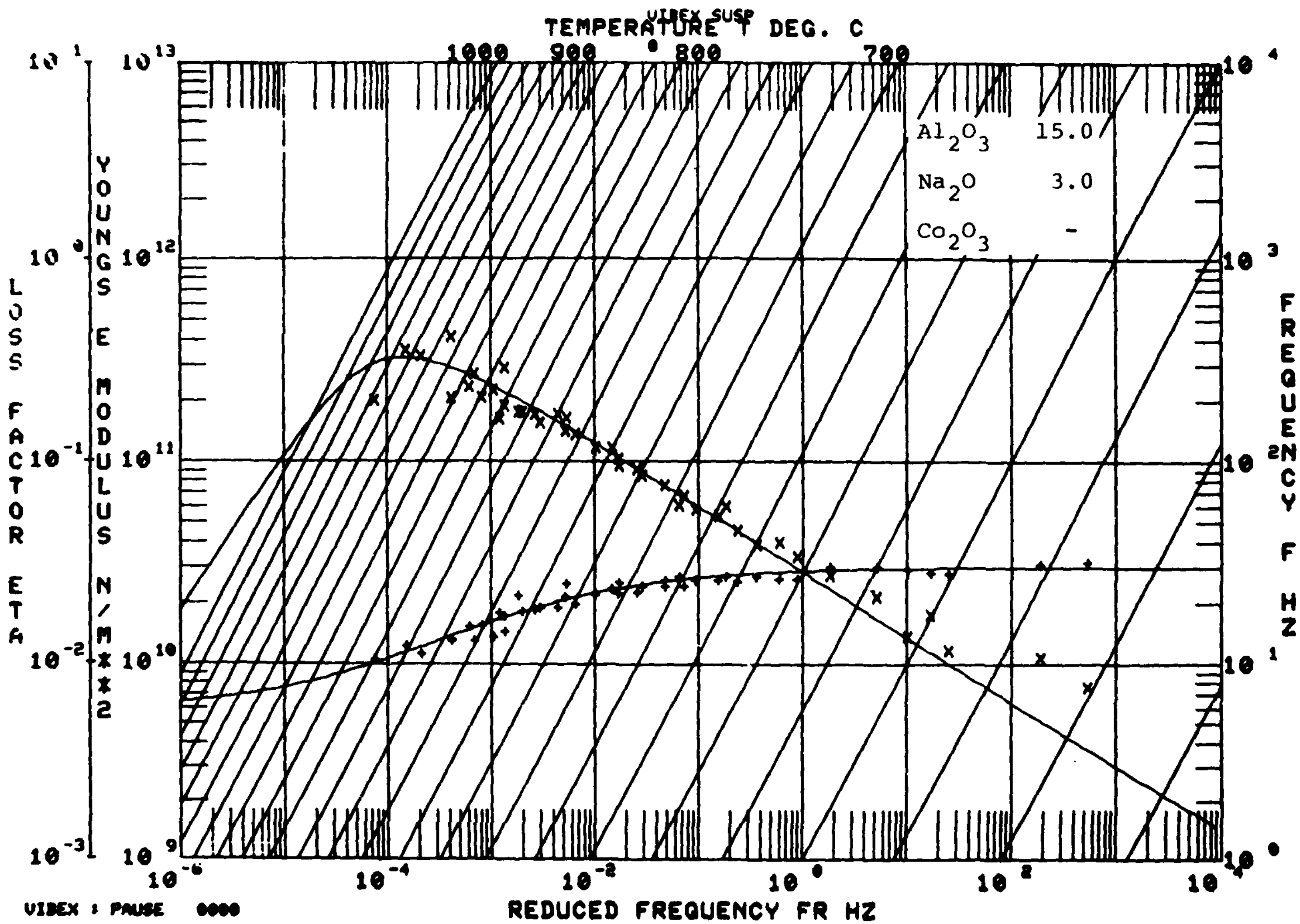

Figure 23. Specimen M29 reduced frequency and temperature nomograph.

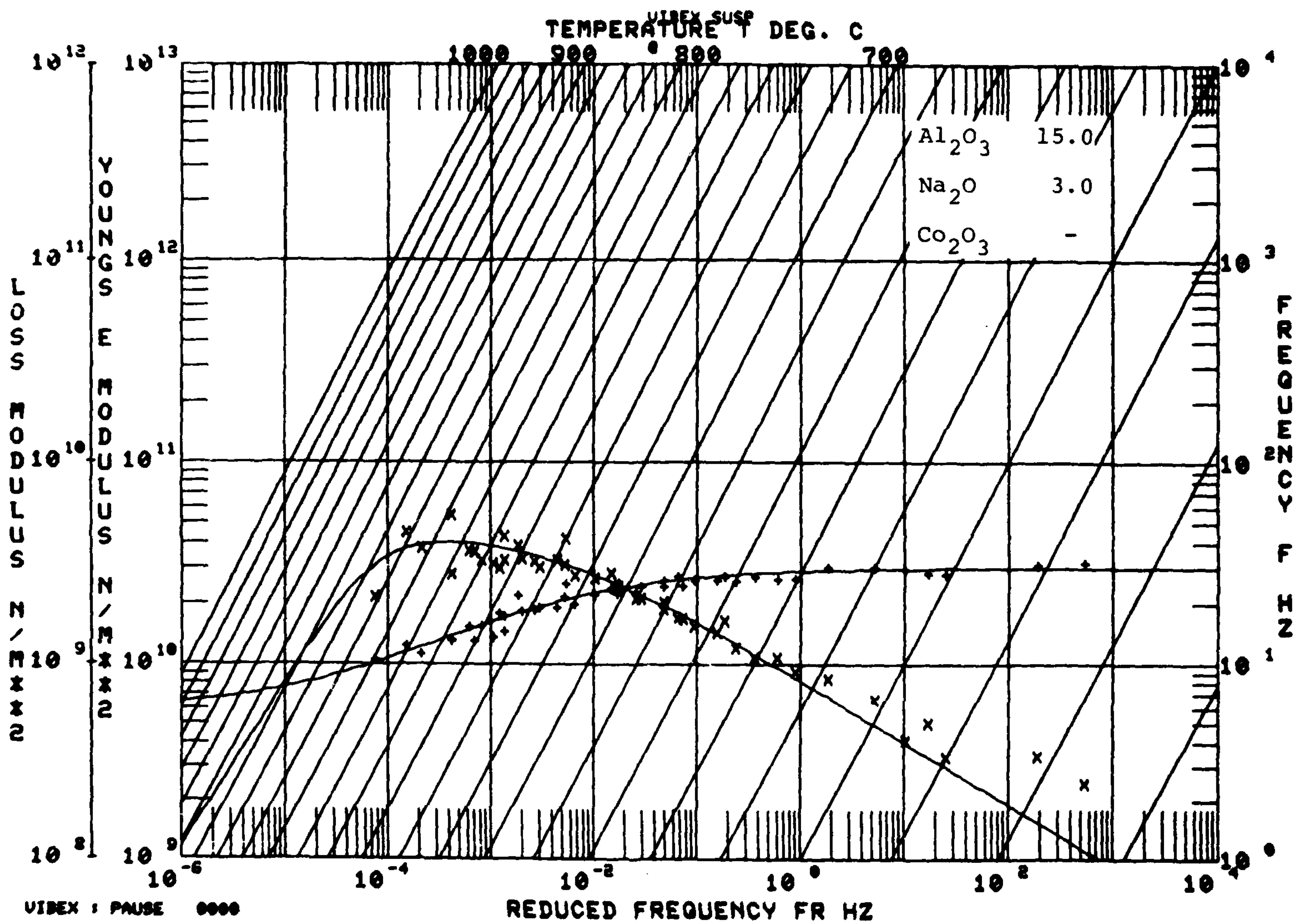

Figure 24. Specimen M29 reduced frequency and temperature nomograph.

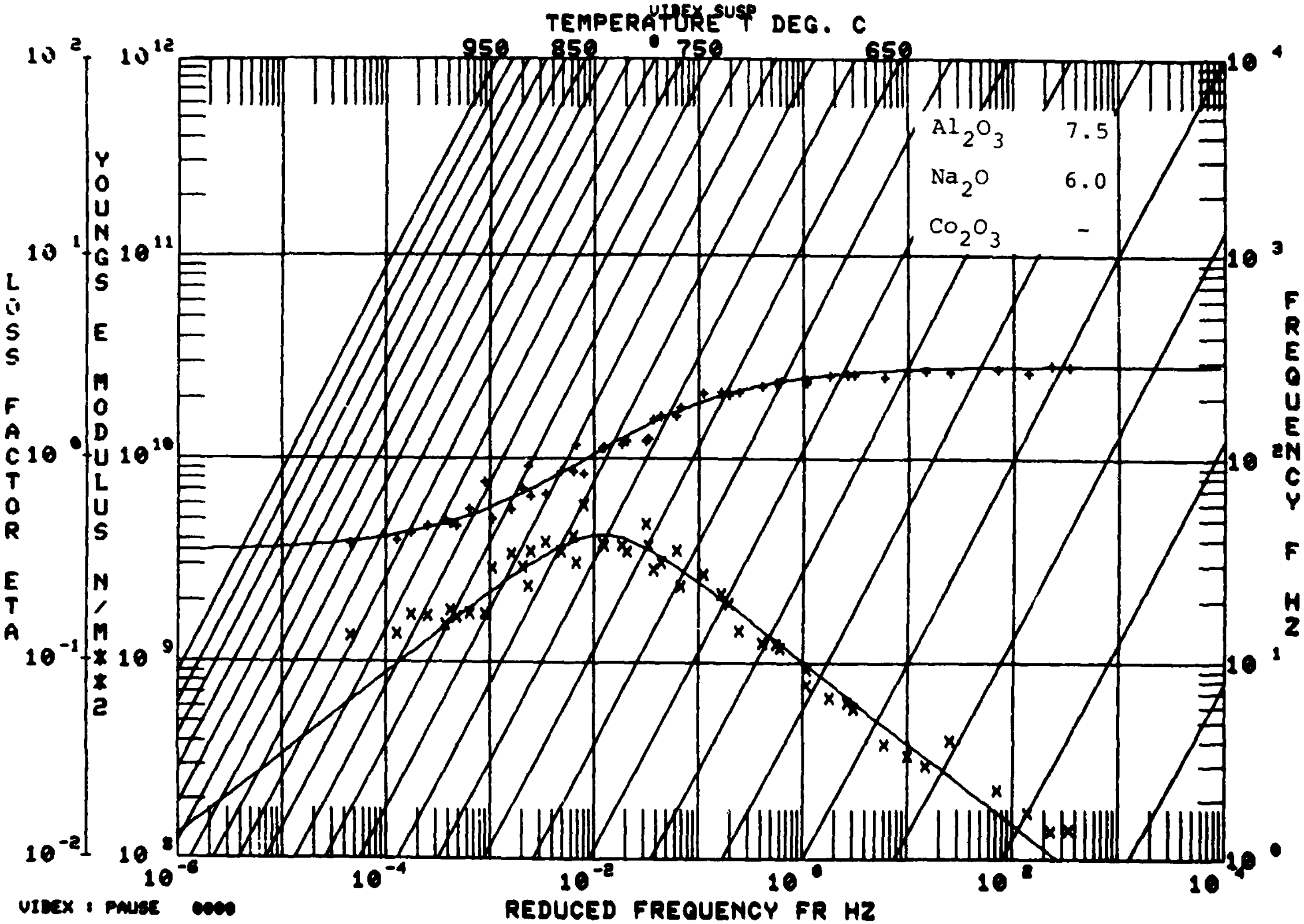

Figure 25. Specimen M49 reduced frequency and temperature nomograph.

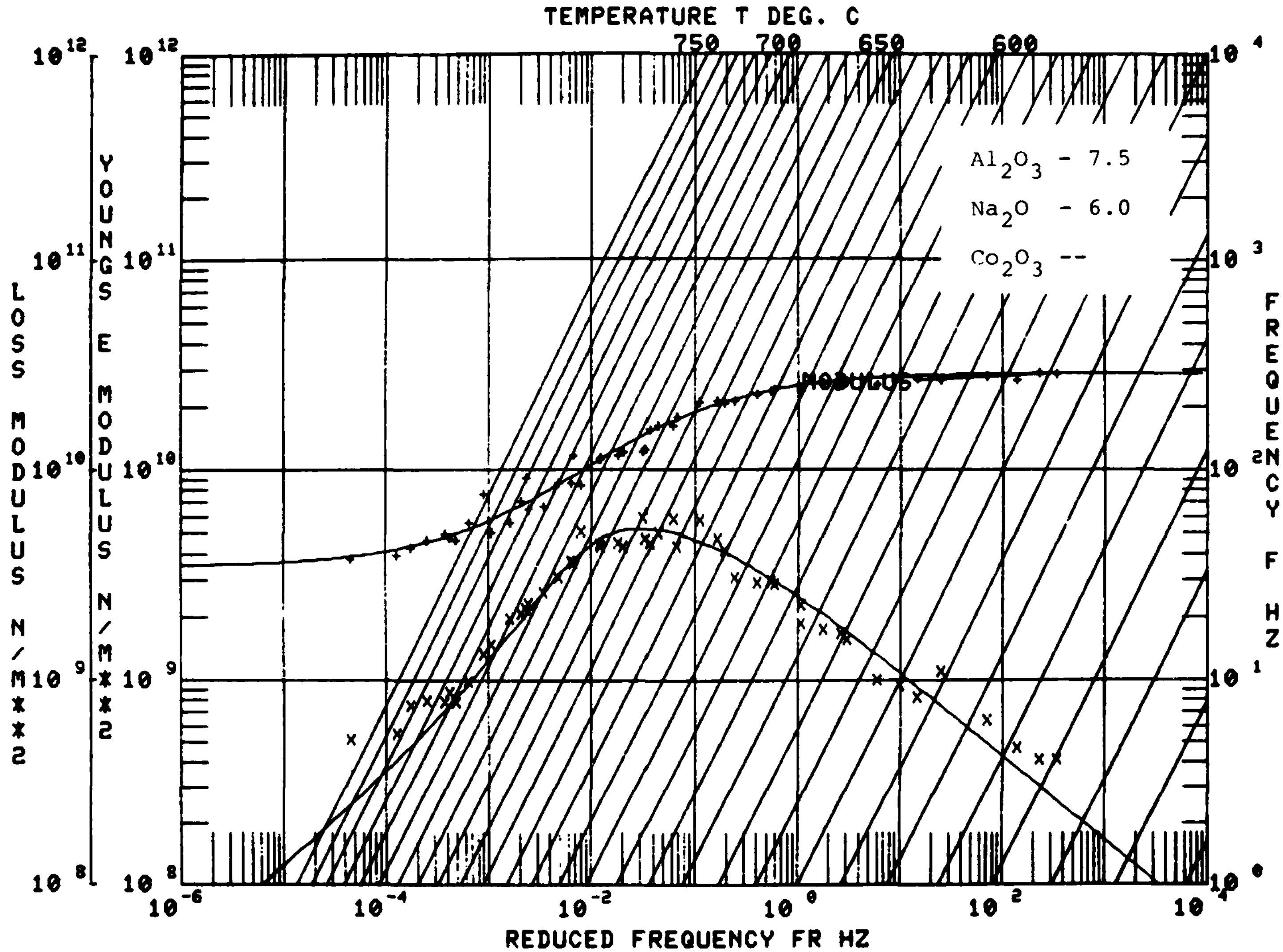

Figure 26. Specimen M49 reduced frequency and temperature nomograph.

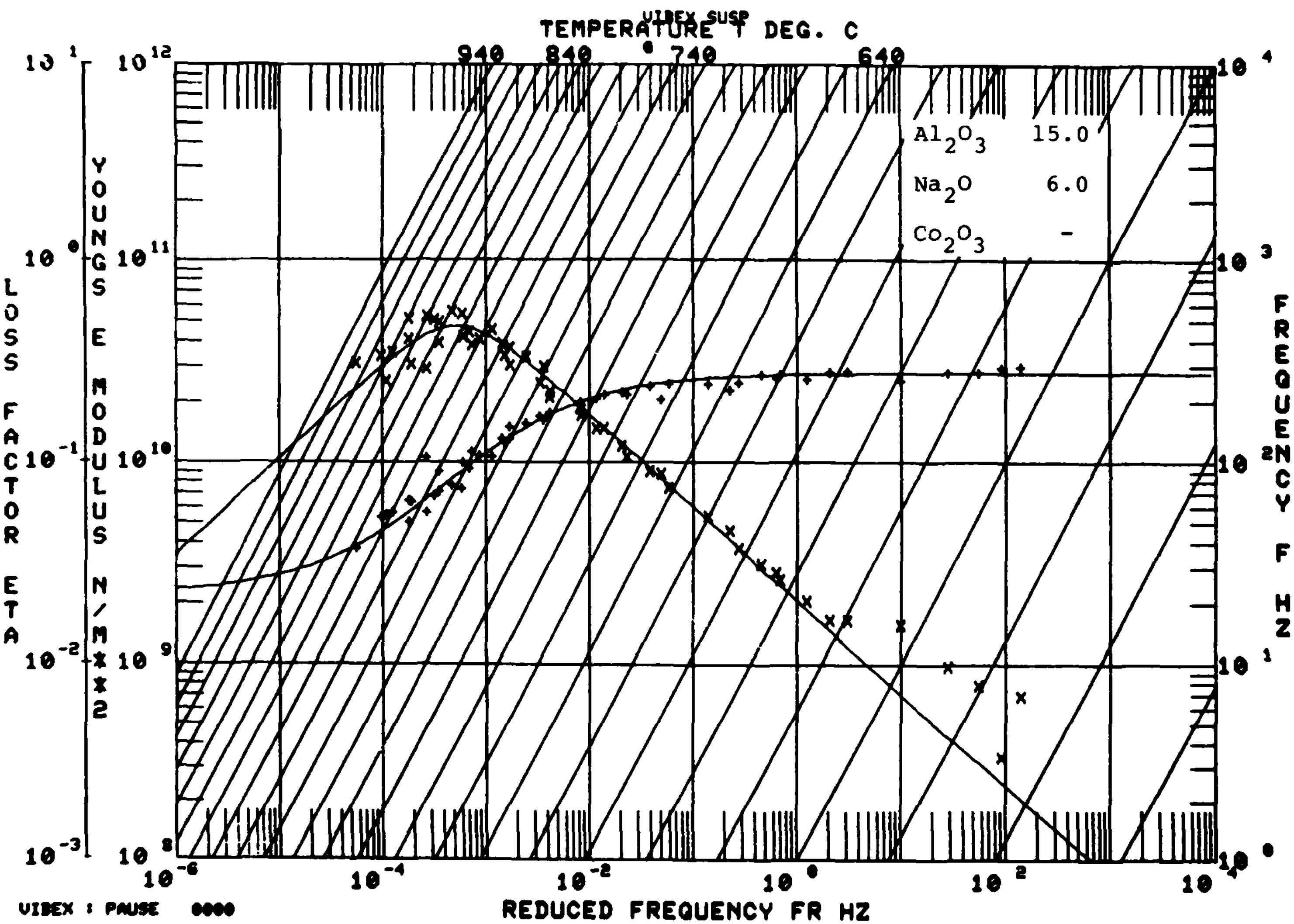

Figure 27. Specimen M32 reduced frequency and temperature nomograph.

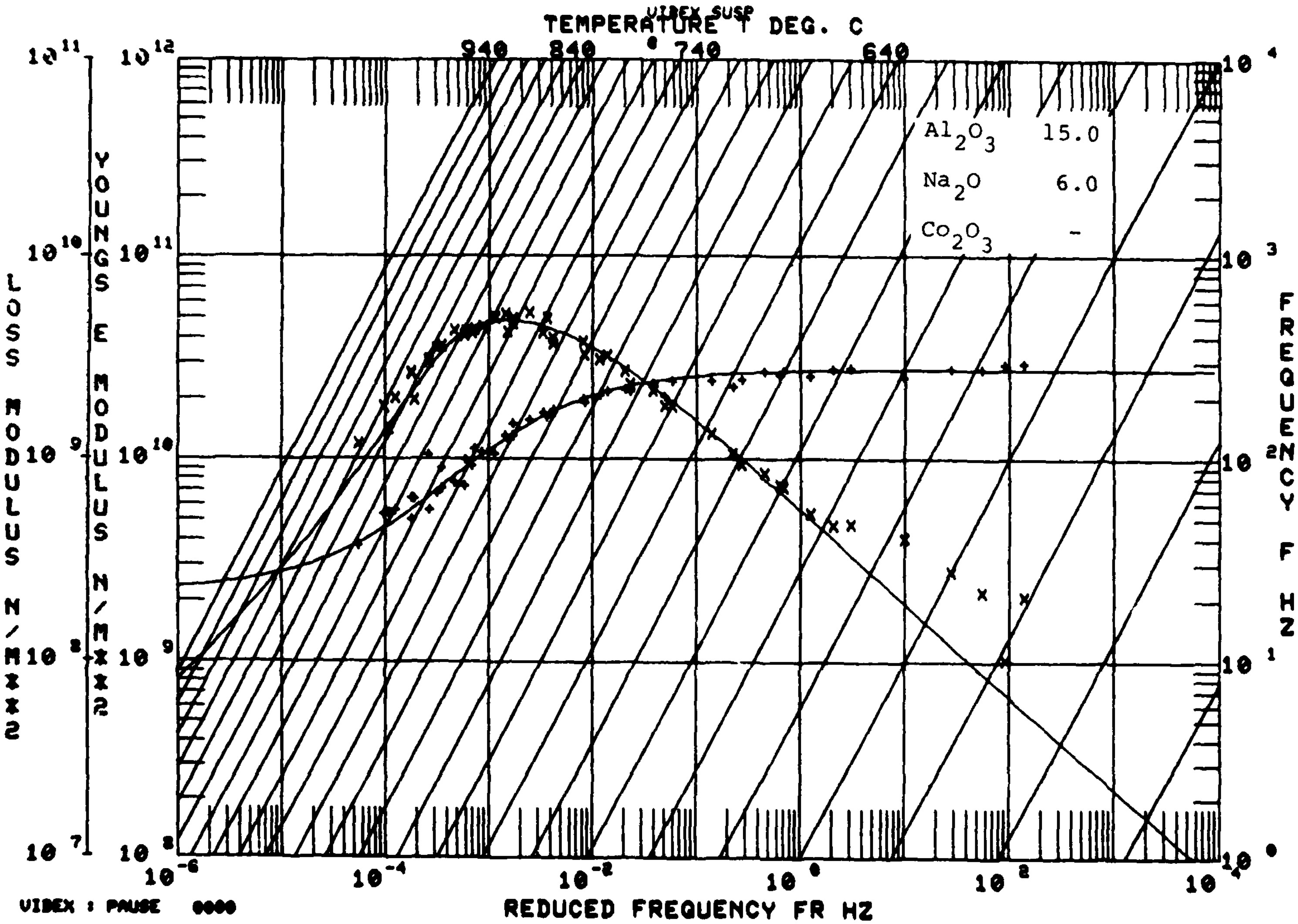

Figure 28. Specimen M32 reduced frequency and temperature nomograph.

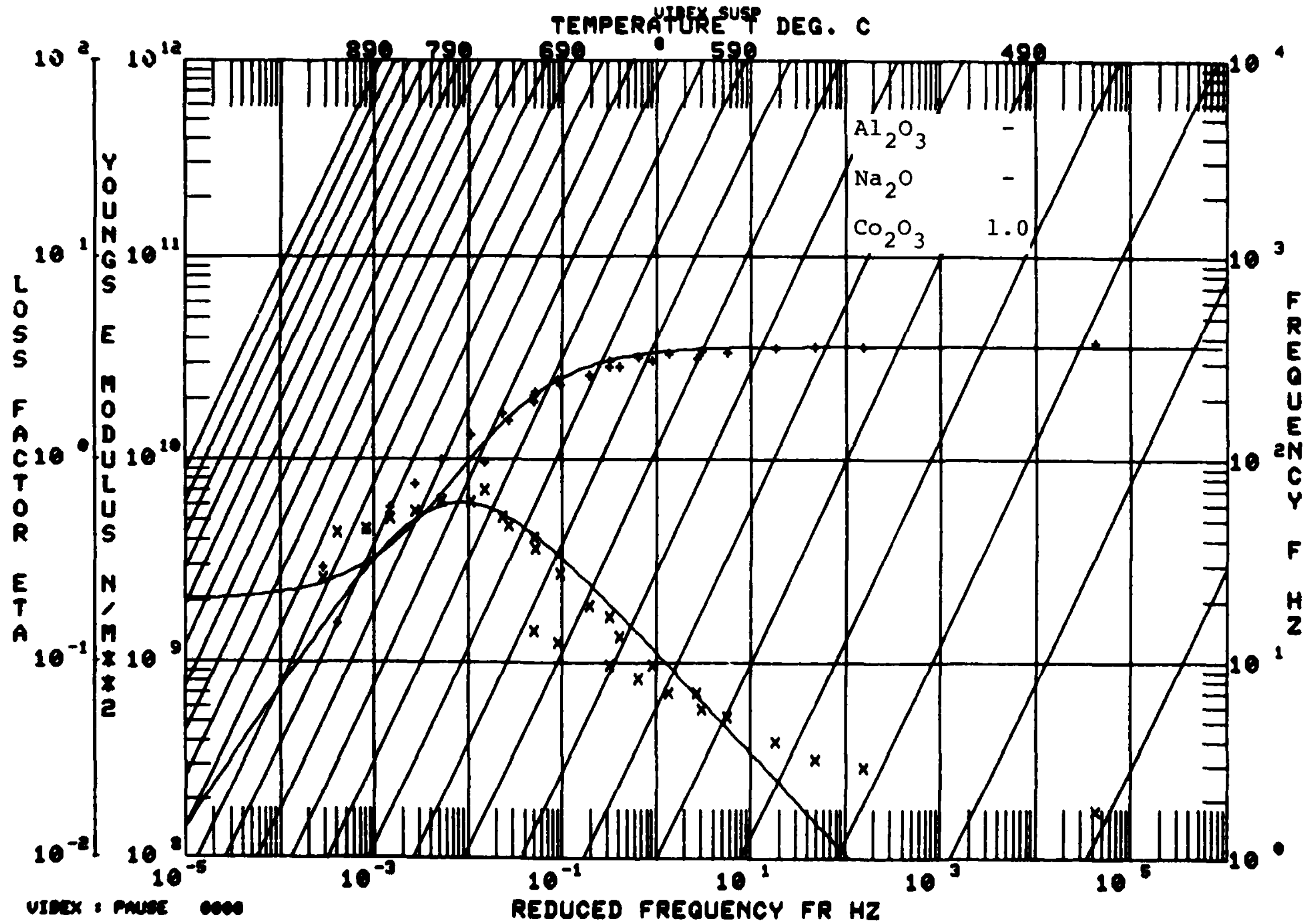

Figure 29. Specimen M26 reduced frequency and temperature nomograph.

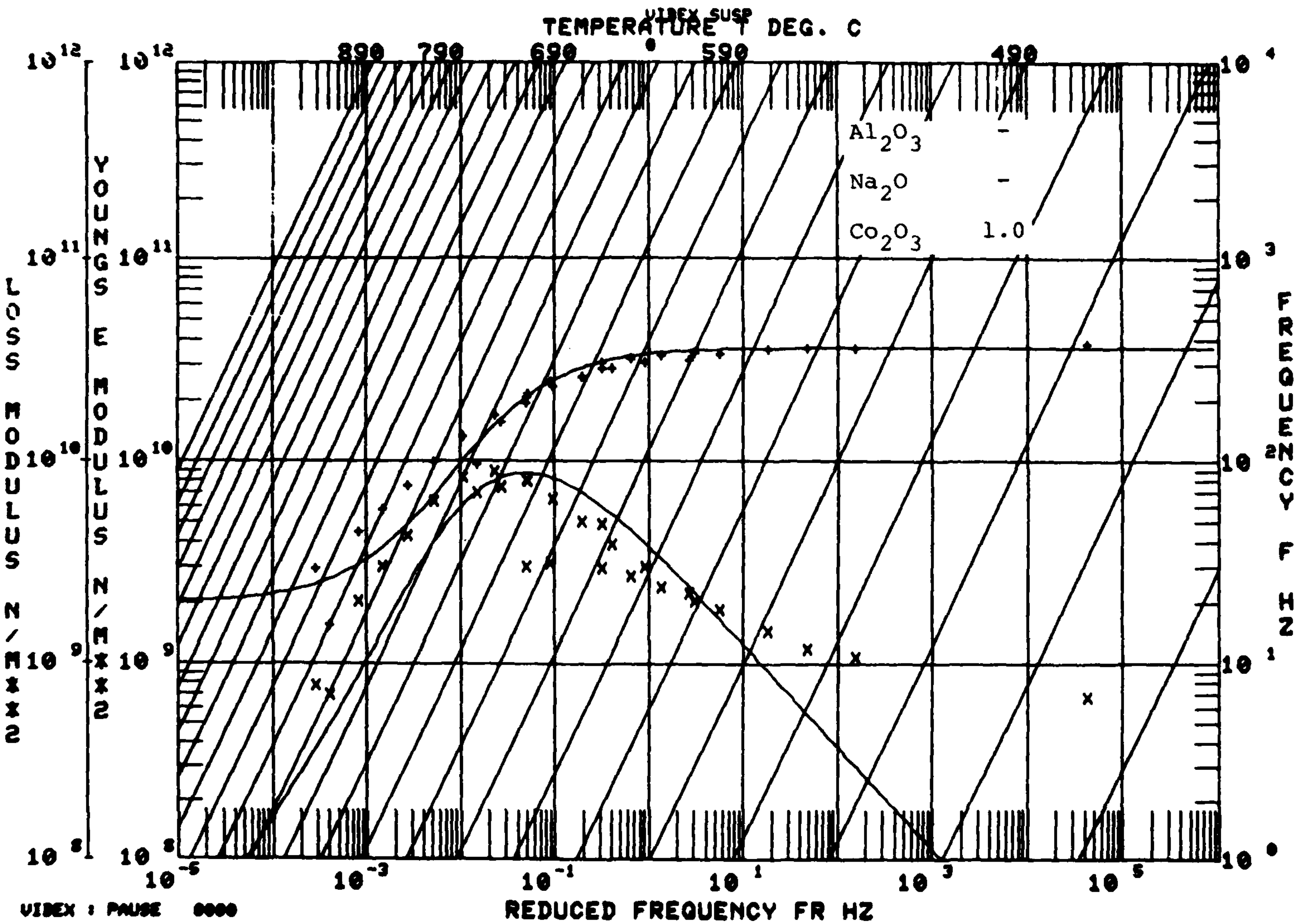

Figure 30. Specimen M26 reduced frequency and temperature nomograph.

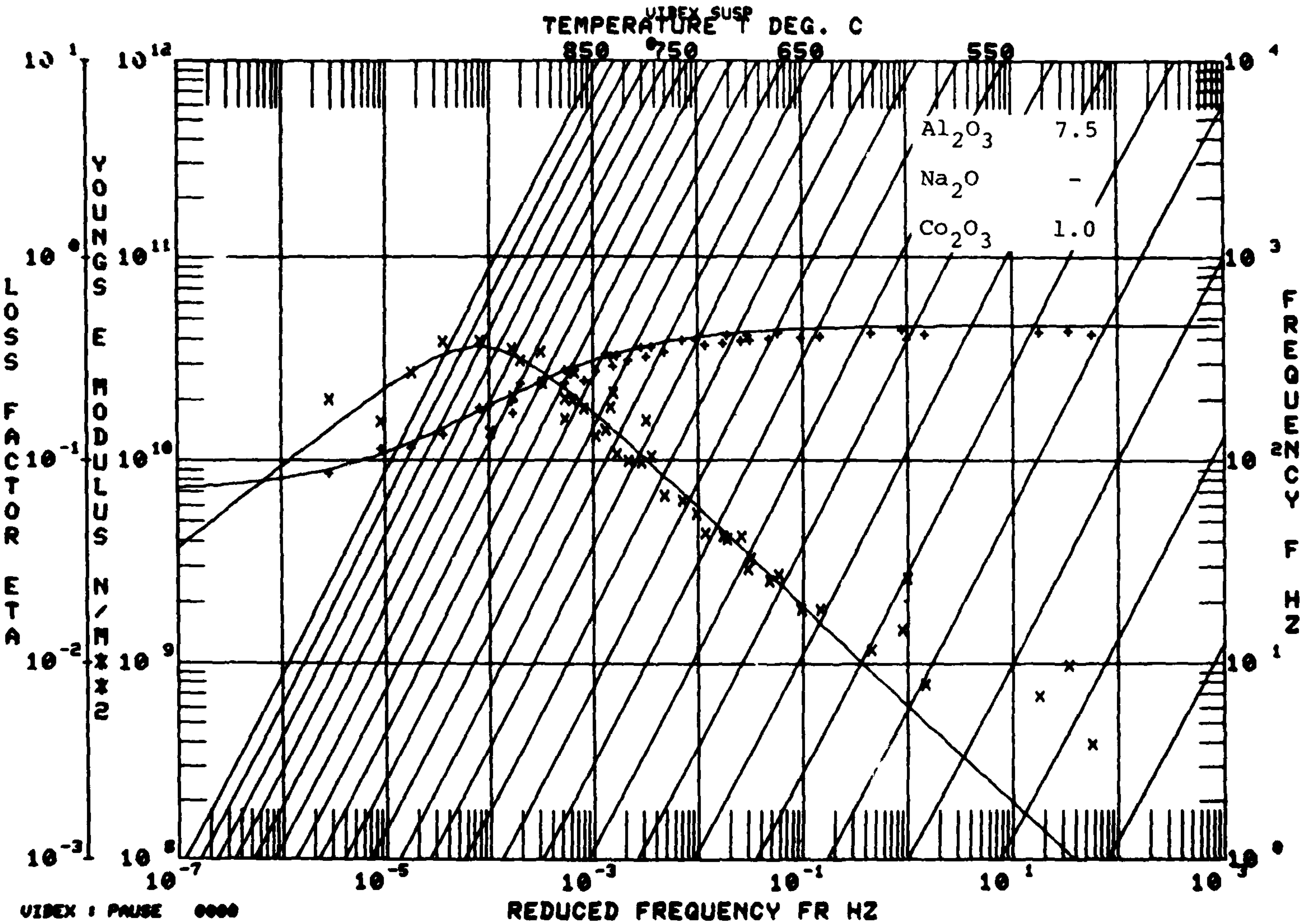

Figure 31. Specimen M12 reduced frequency and temperature nomograph.

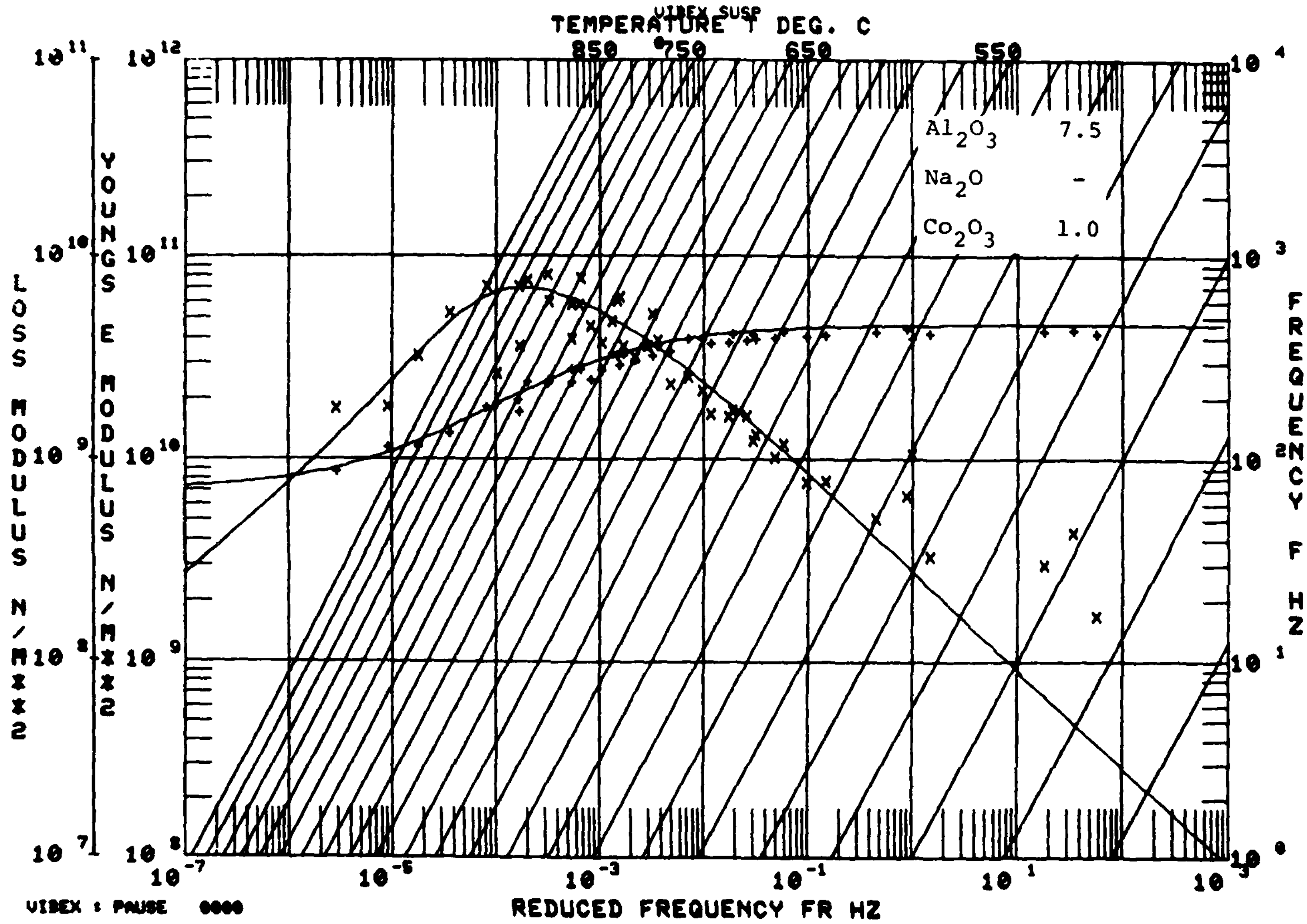

Figure 32. Specimen M12 reduced frequency and temperature nomograph.

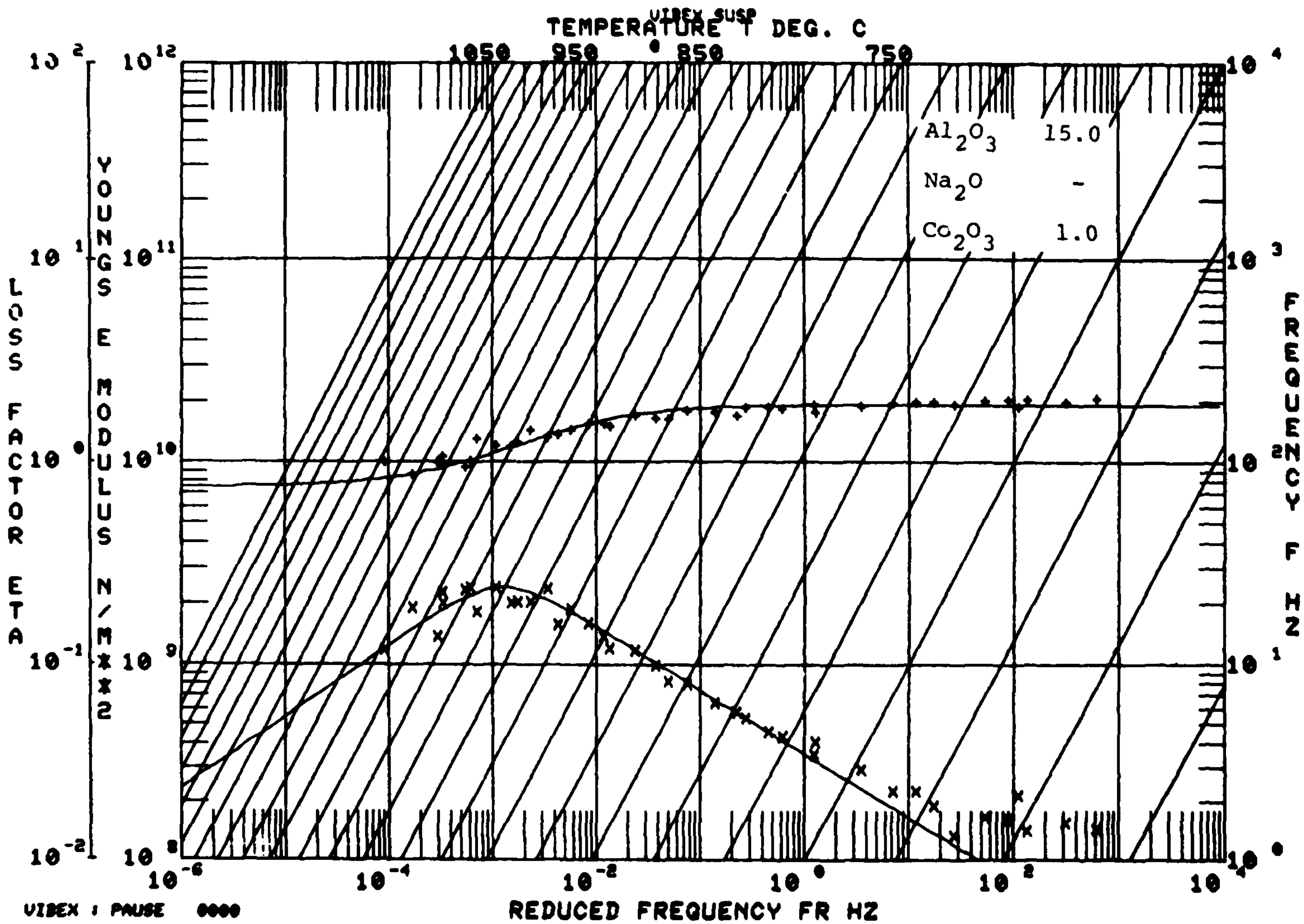

Figure 33. Specimen M21 reduced frequency and temperature nomograph.

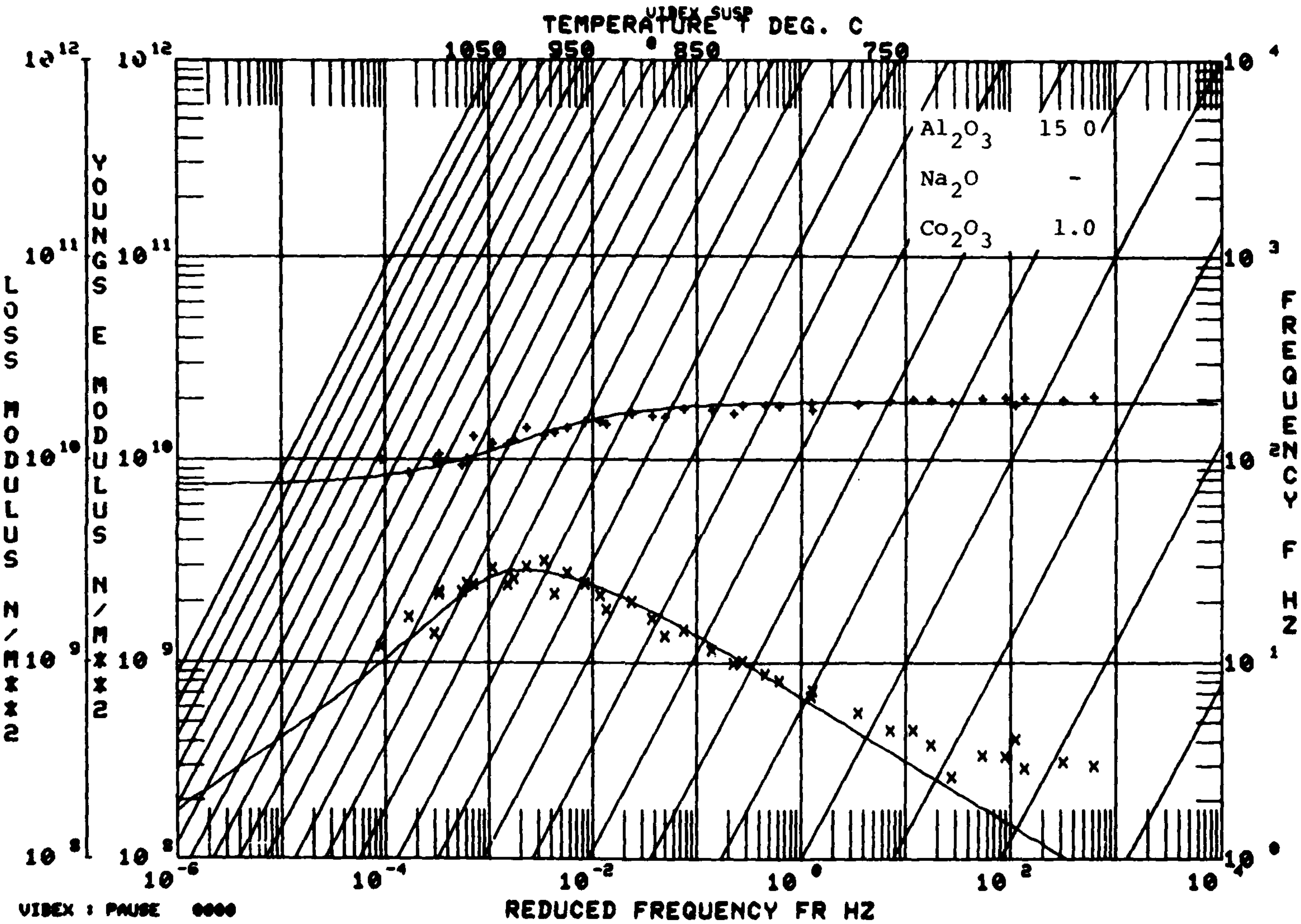

Figure 34. Specimen M21 reduced frequency and temperature nomograph

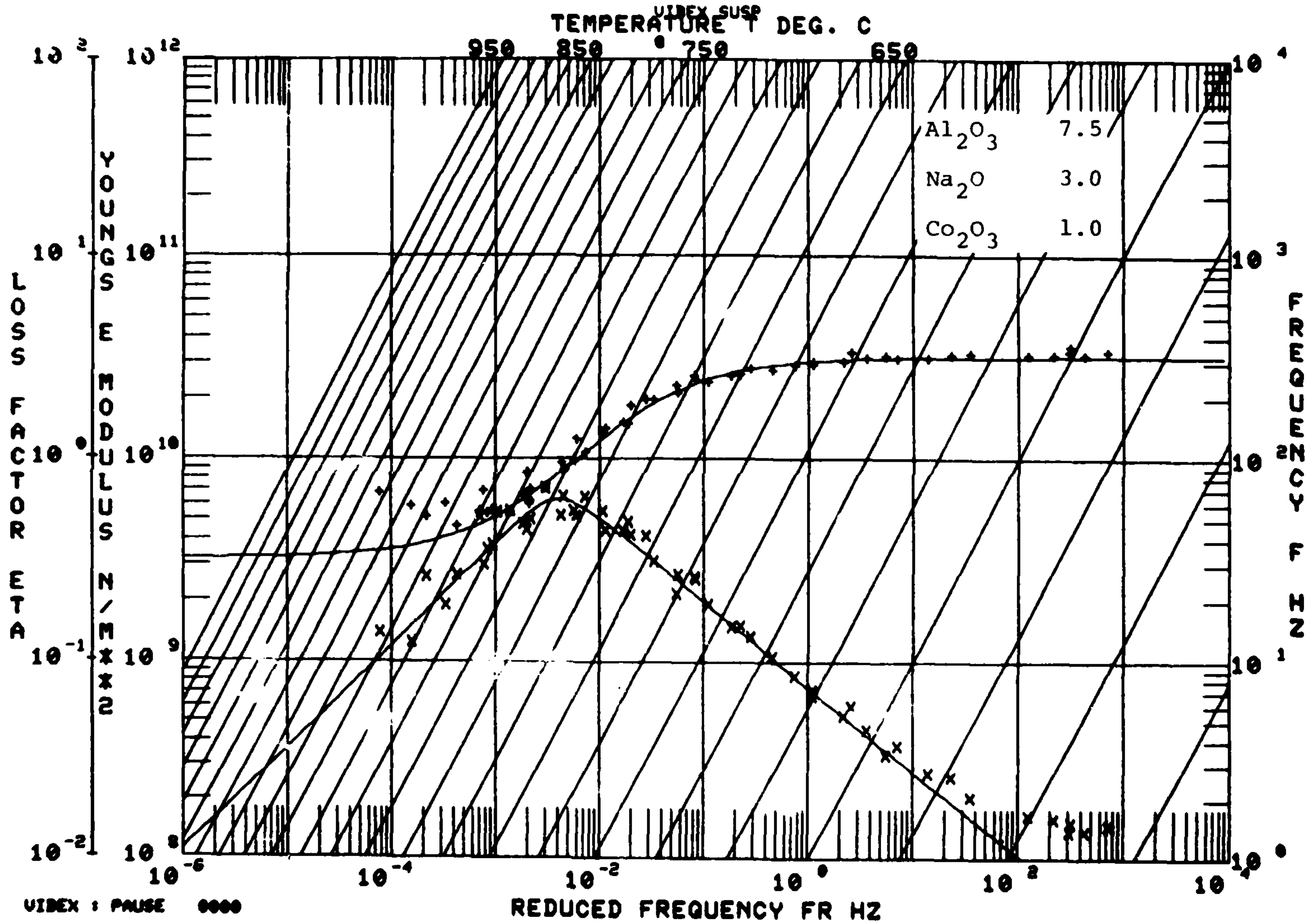

Figure 35. Specimen M35 reduced frequency and temperature nomograph.

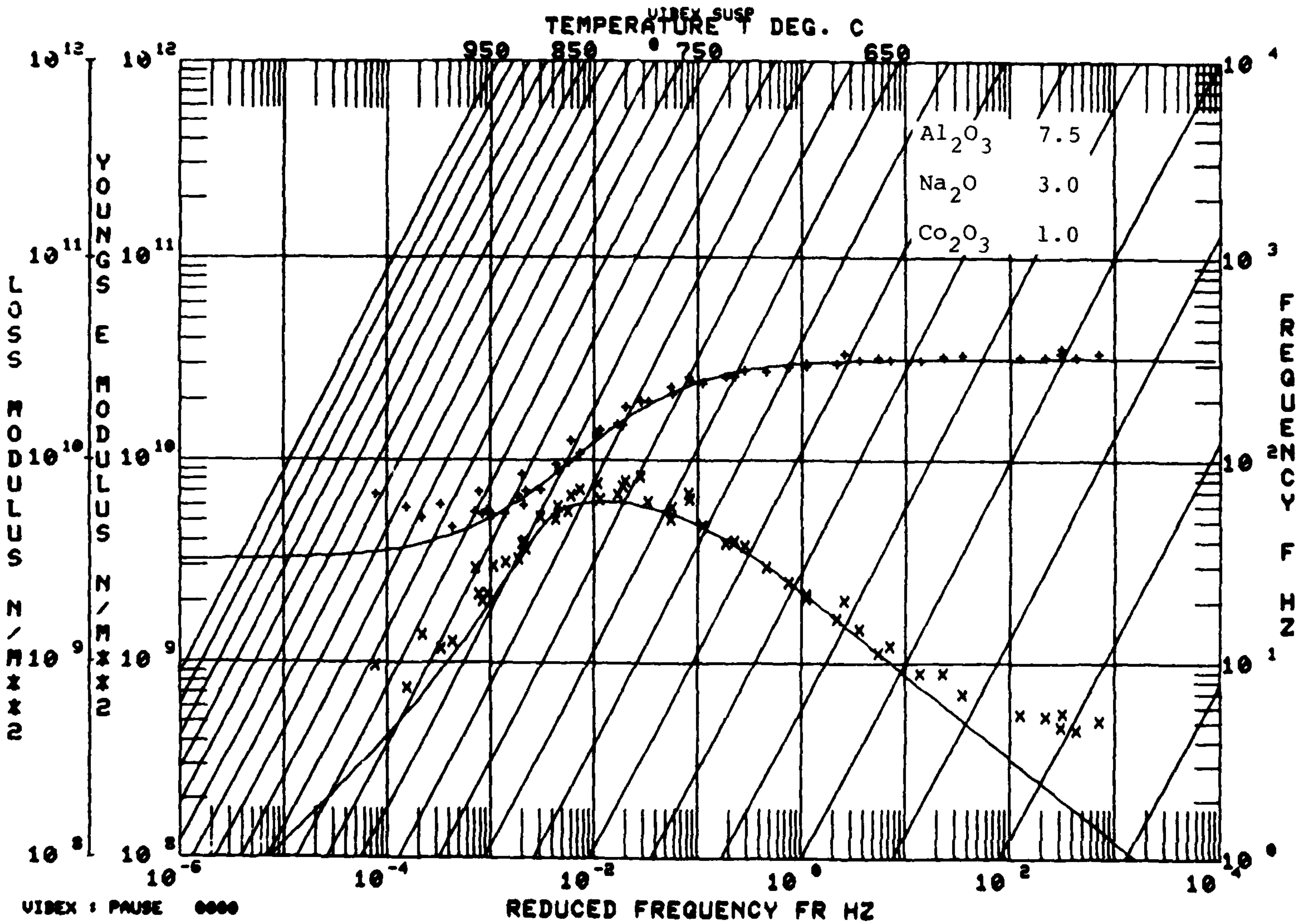

Figure 36. Specimen M35 reduced frequency and temperature nomograph.

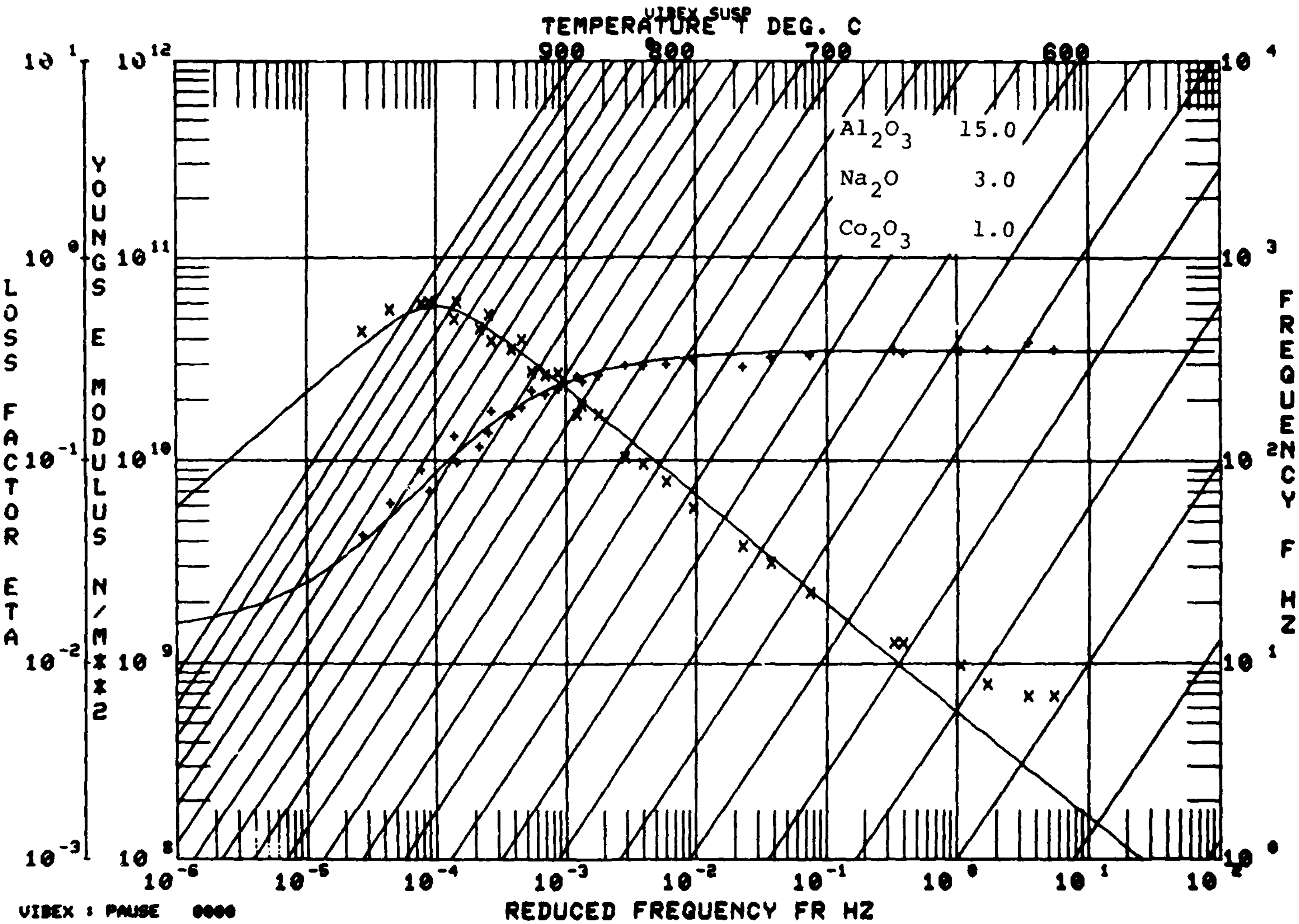

Figure 37. Specimen M24 reduced frequency and temperature nomograph.

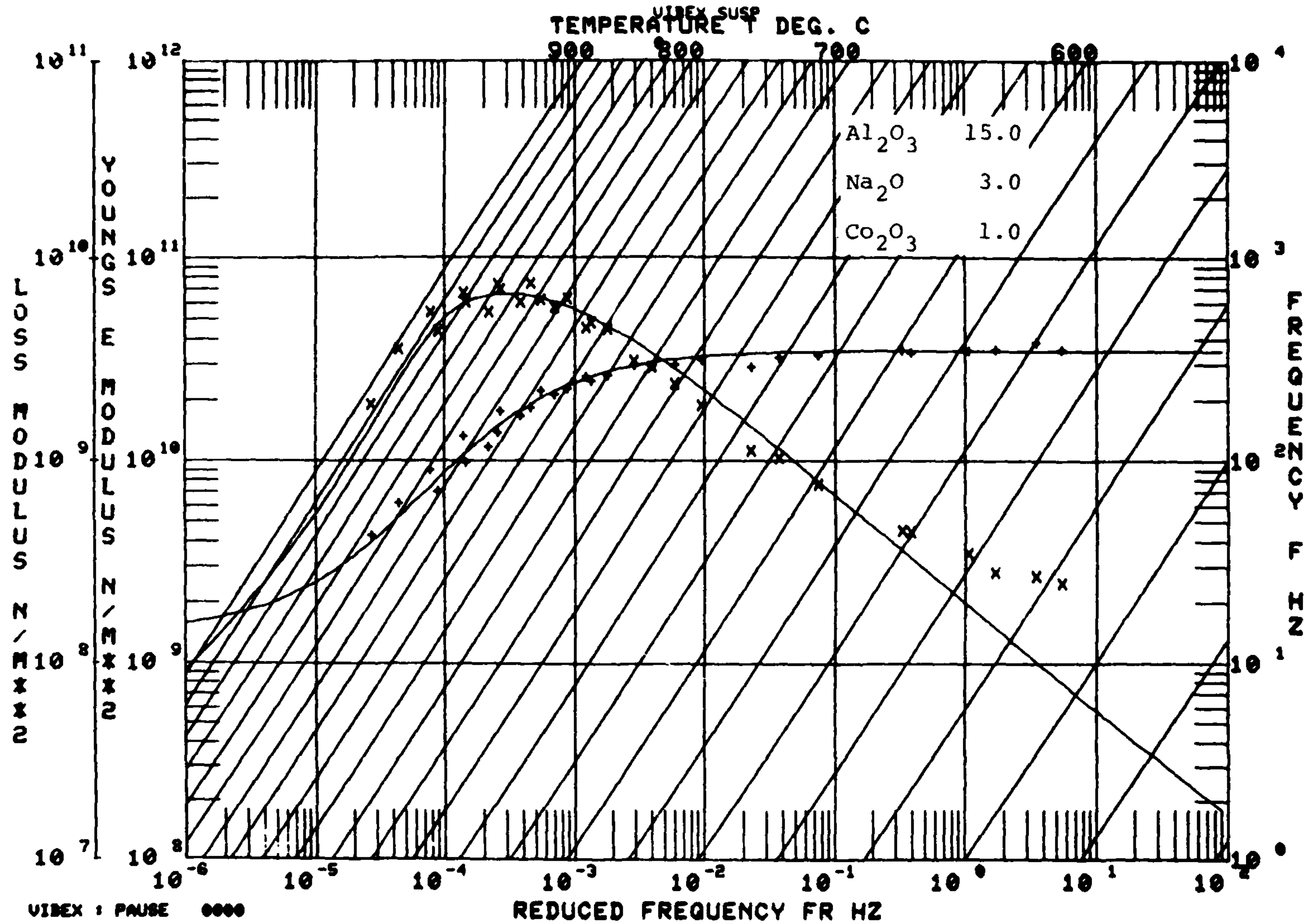

Figure 38. Specimen M24 reduced frequency and temperature nomograph.

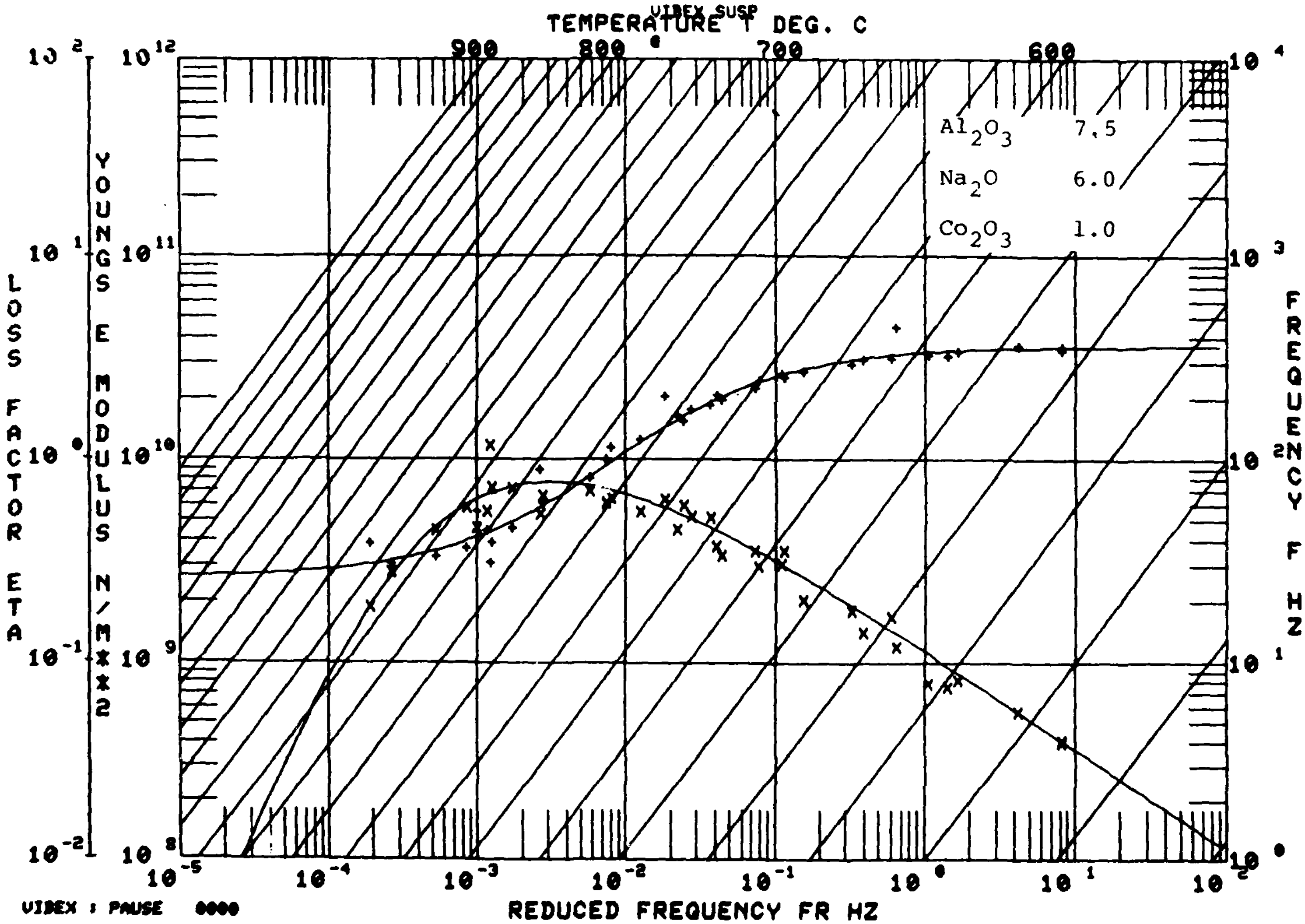

Figure 39. Specimen M11 reduced frequency and temperature nomograph.

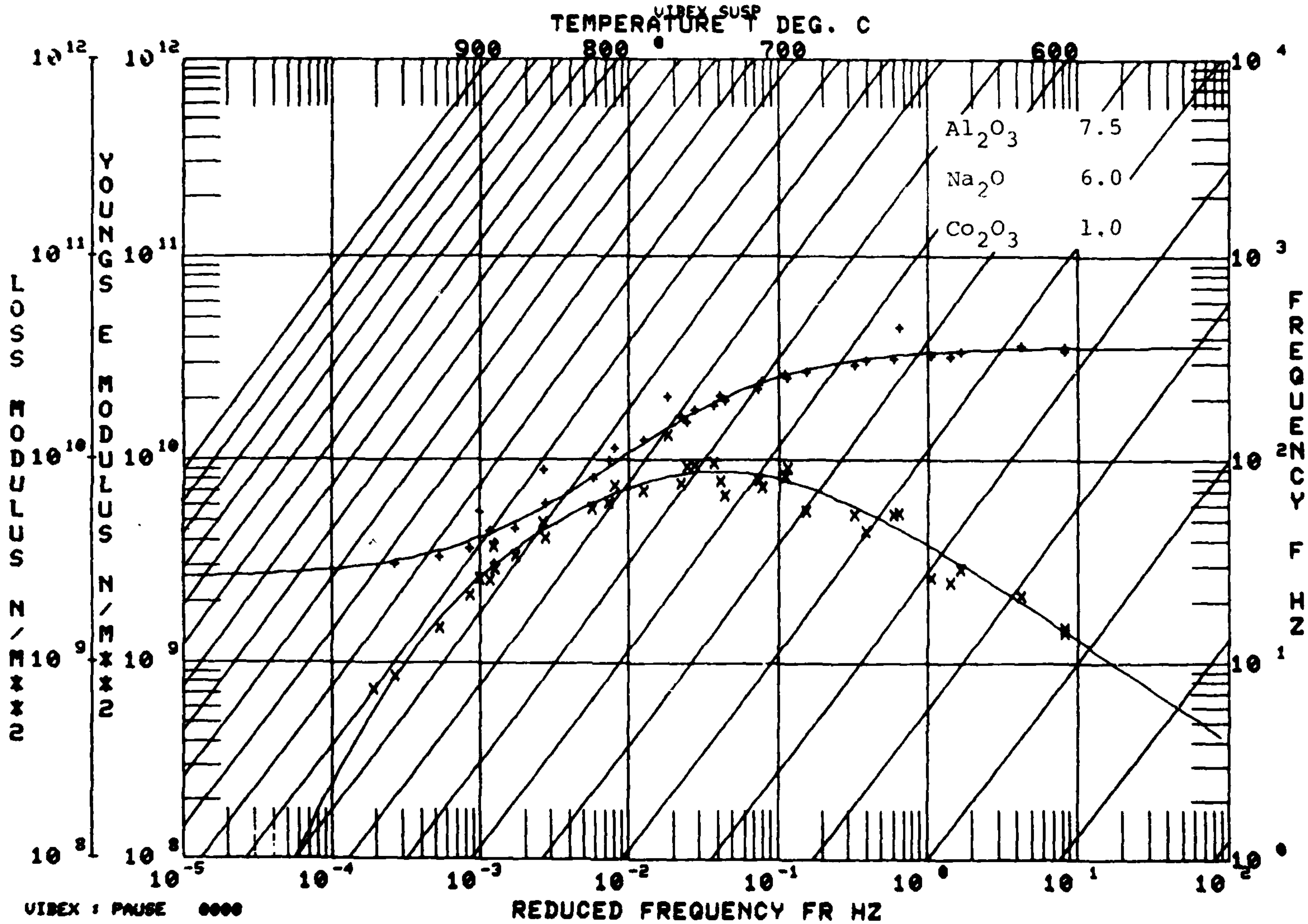

Figure 40. Specimen M11 reduced frequency and temperature nomograph.

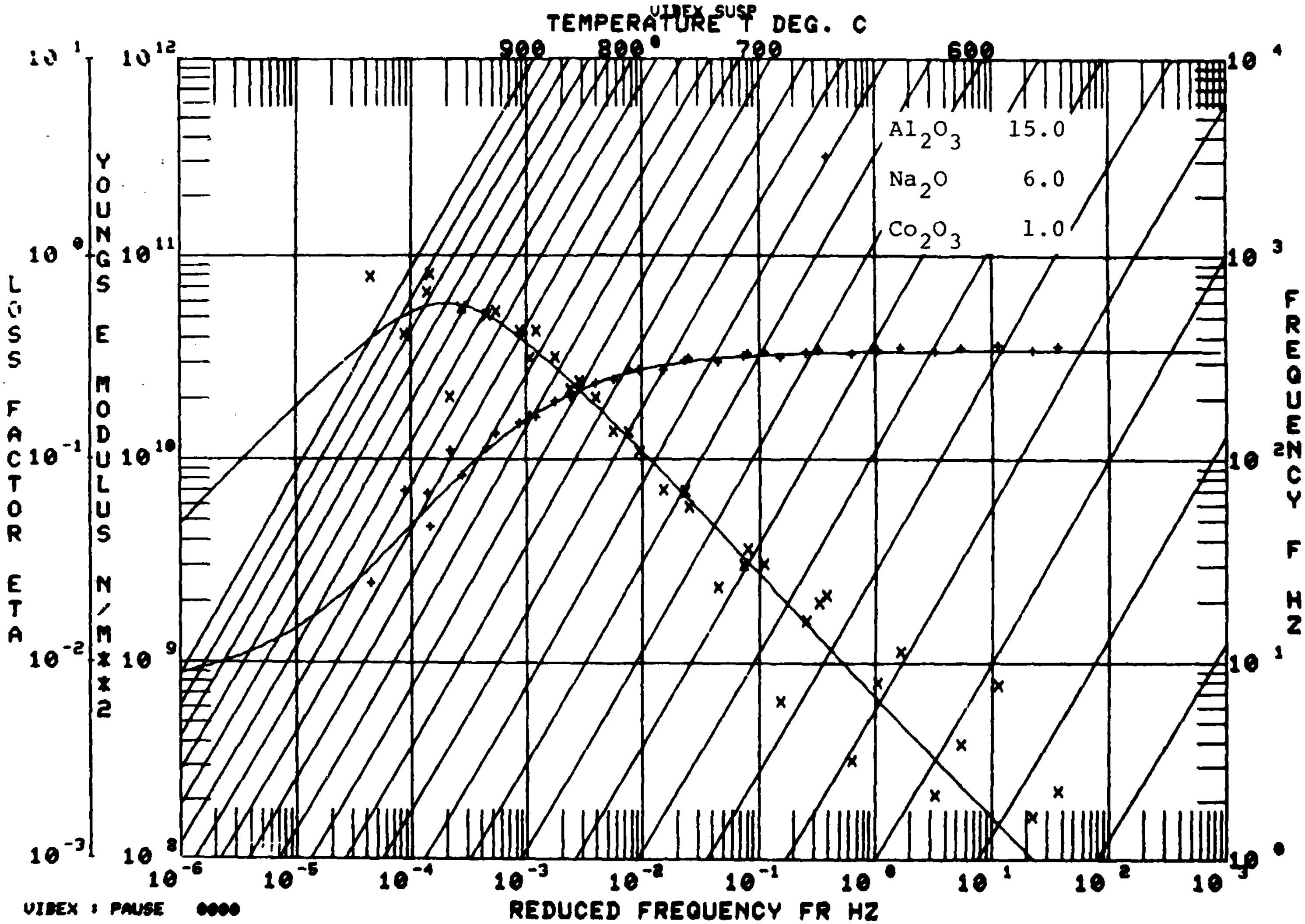

Figure 41. Specimen M22 reduced frequency and temperature nomograph.

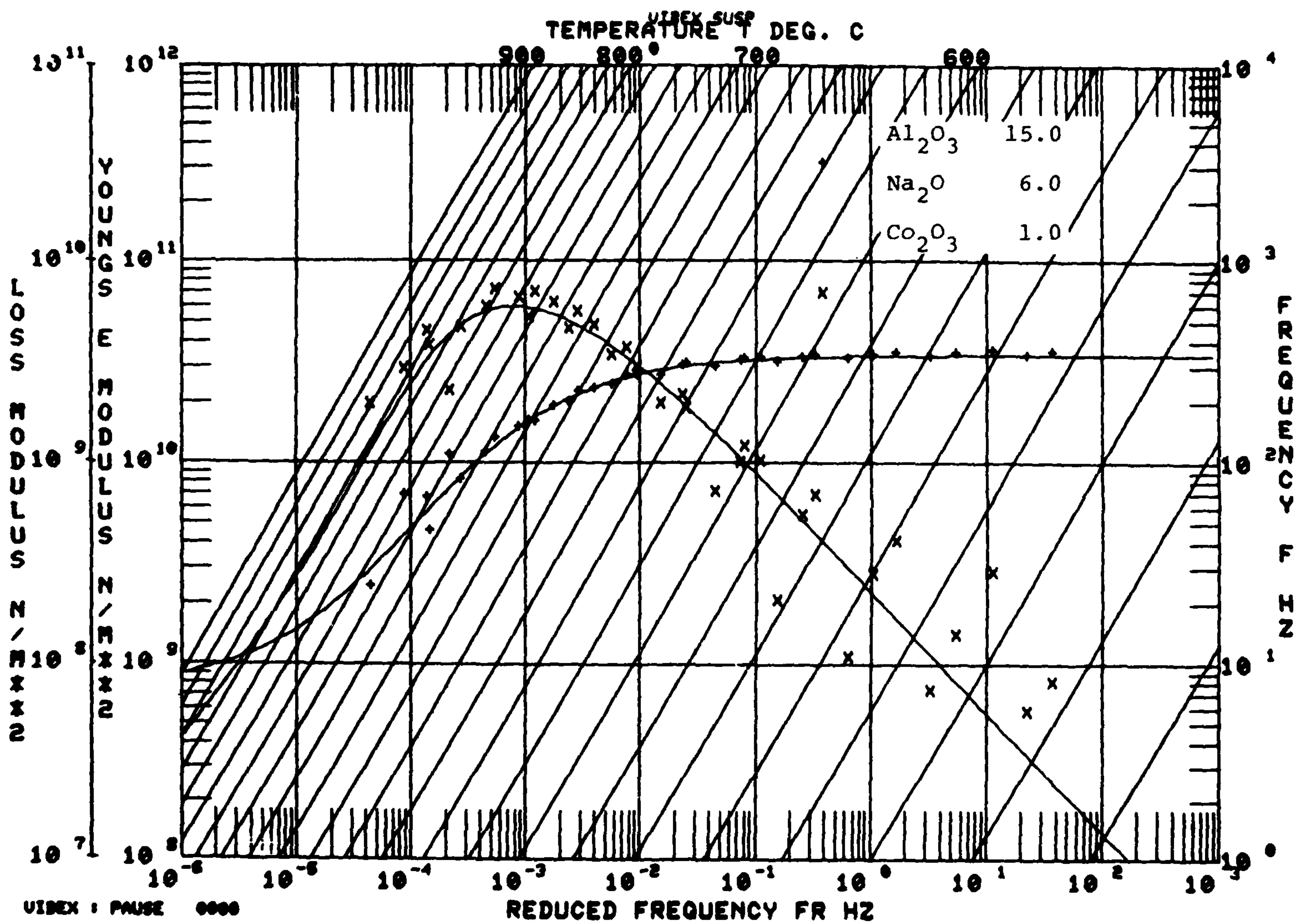

Figure 42. Specimen M22 reduced frequency and temperature nomograph.

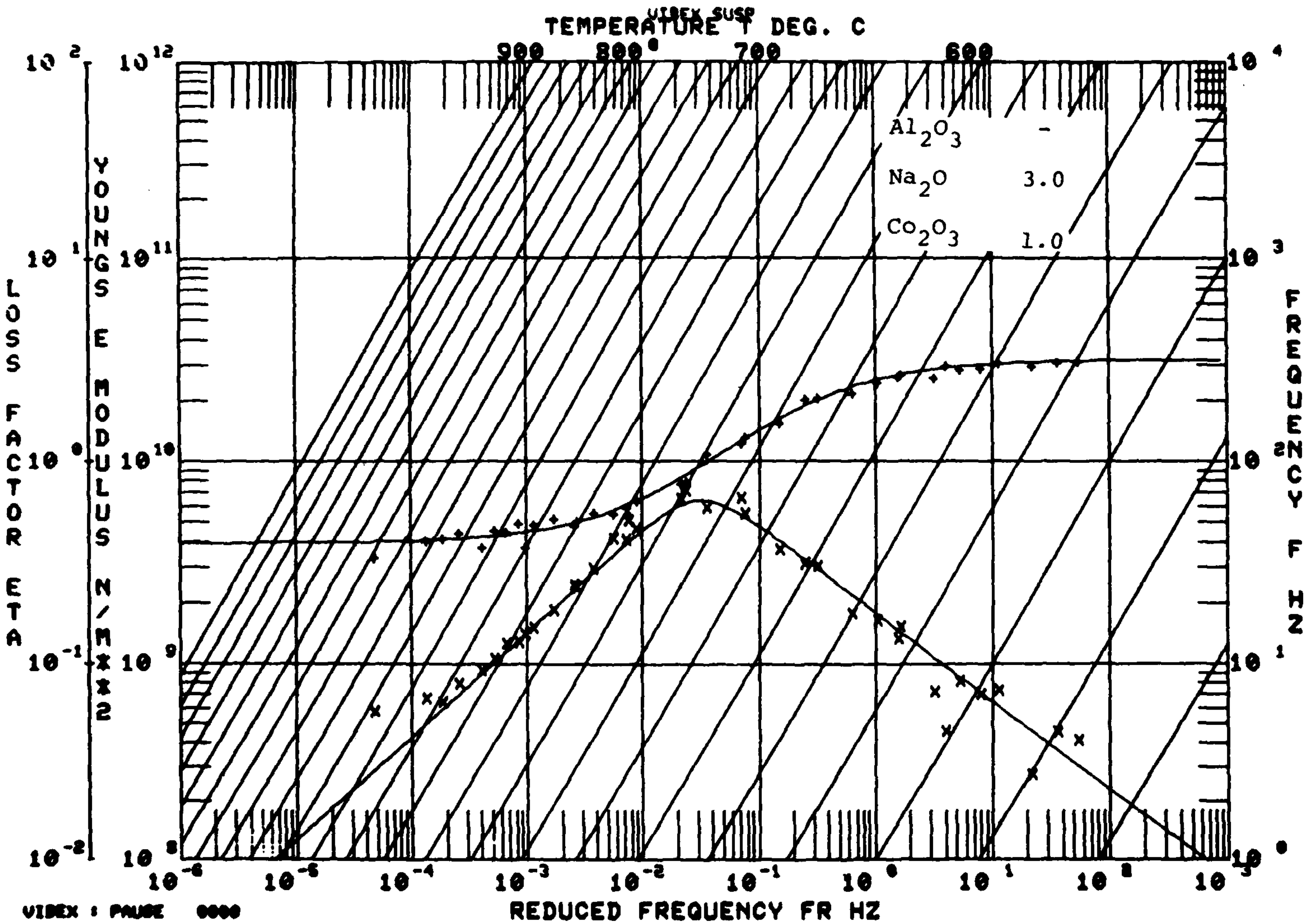

Figure 43. Specimen M14 reduced frequency and temperature nomograph.

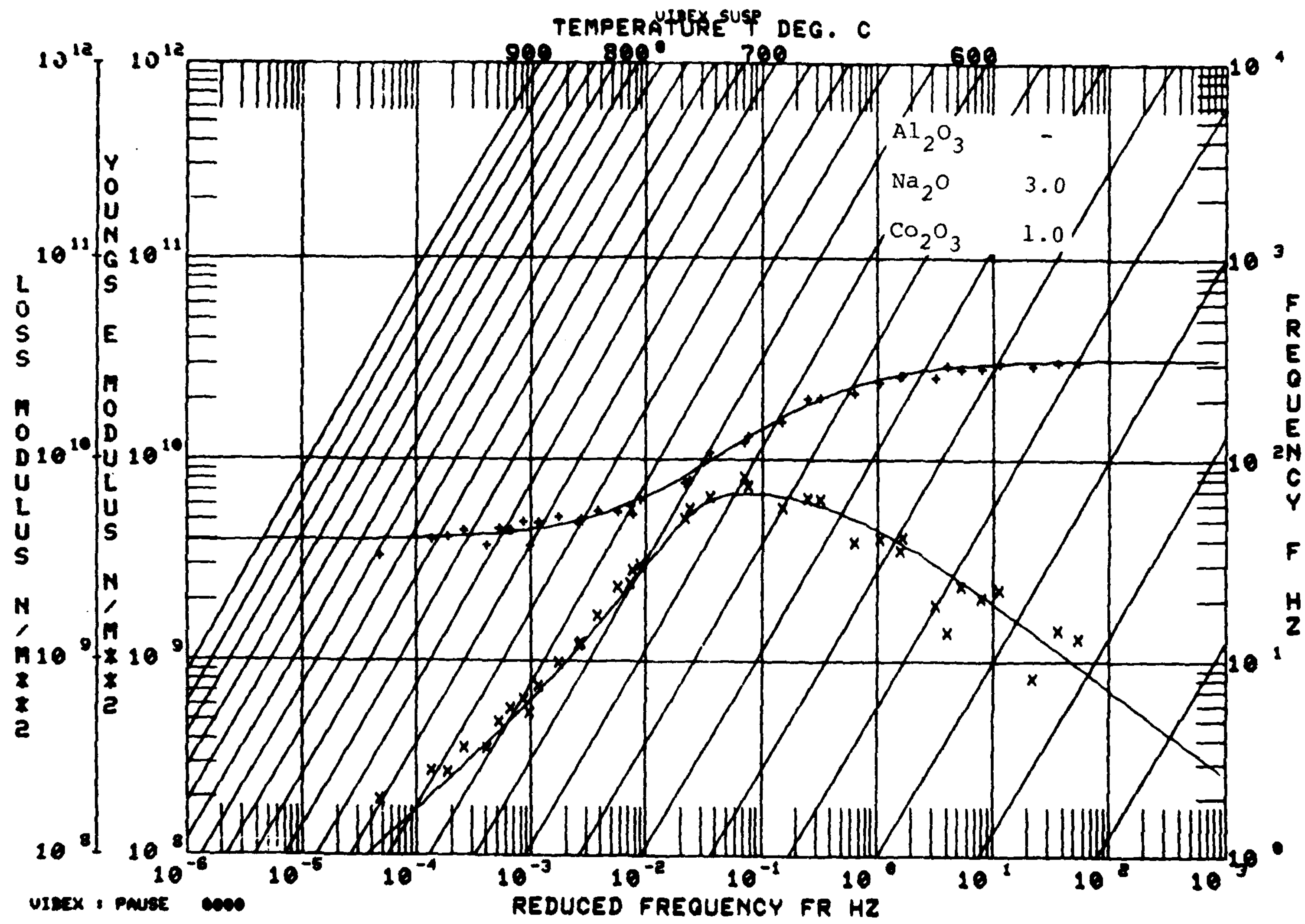

Figure 44. Specimen M14 reduced frequency and temperature nomograph.

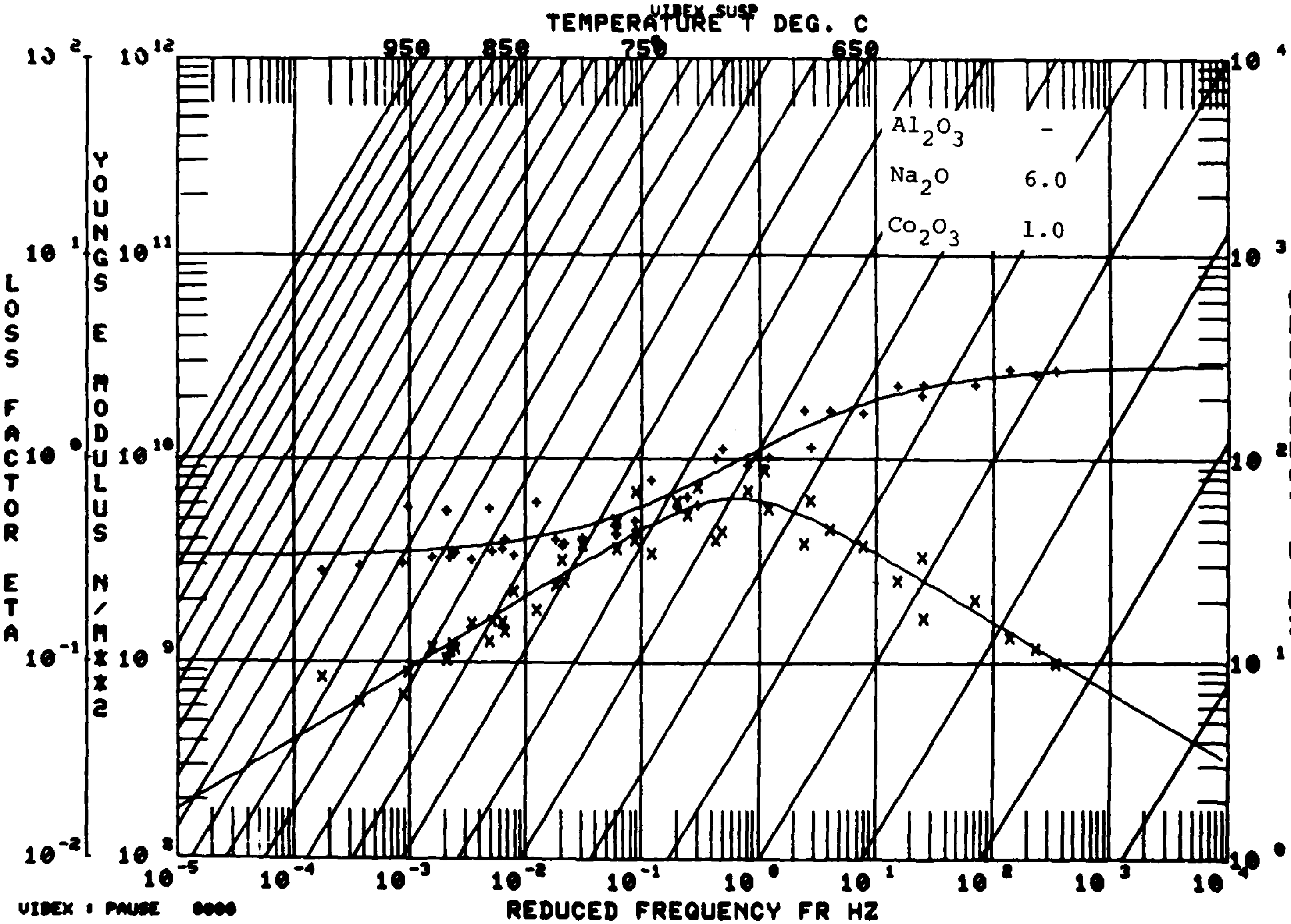

Figure 45. Specimen M48 reduced frequency and temperature nomograph.

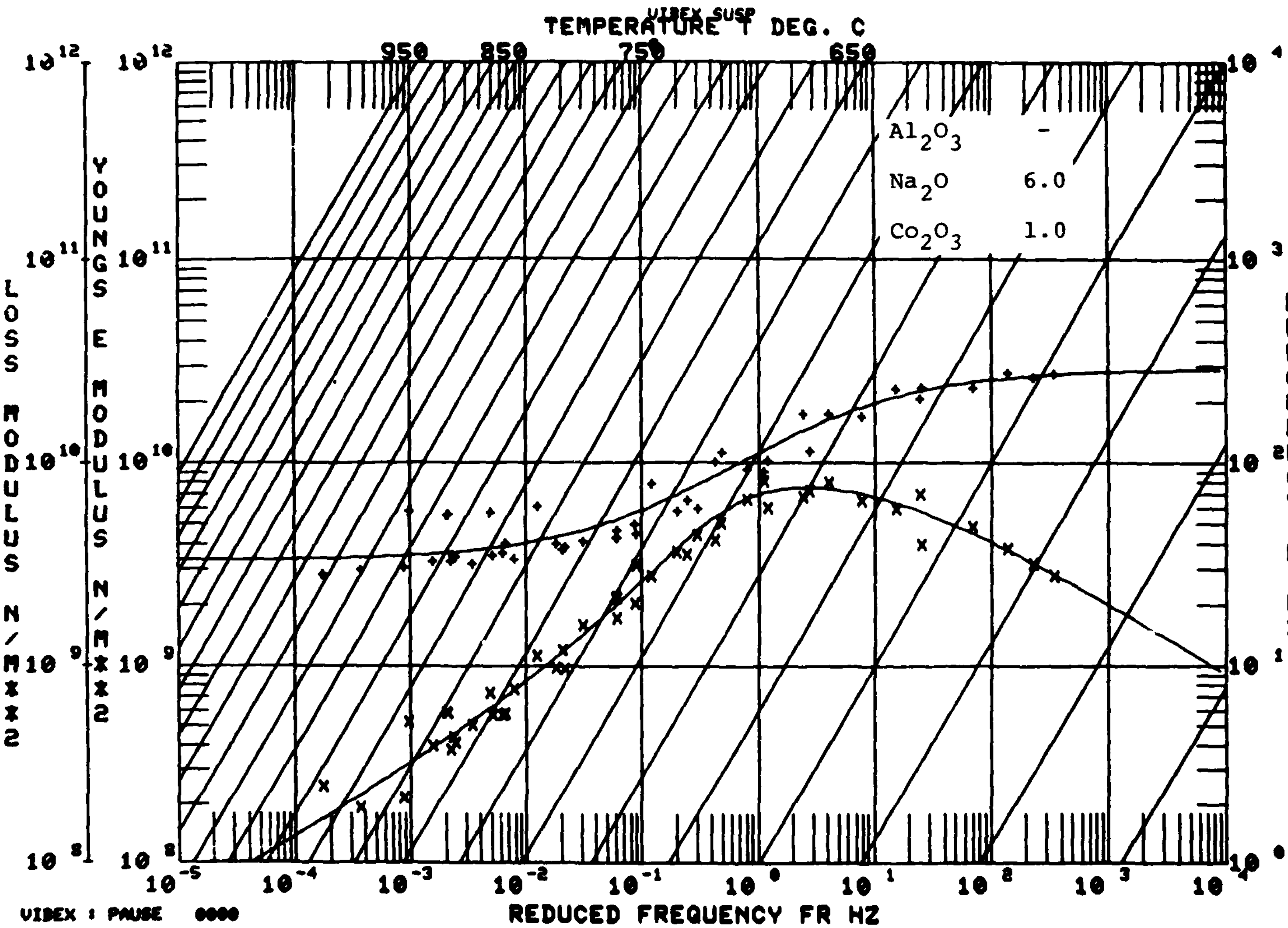

Figure 46. Specimen M48 reduced frequency and temperature nomograph.

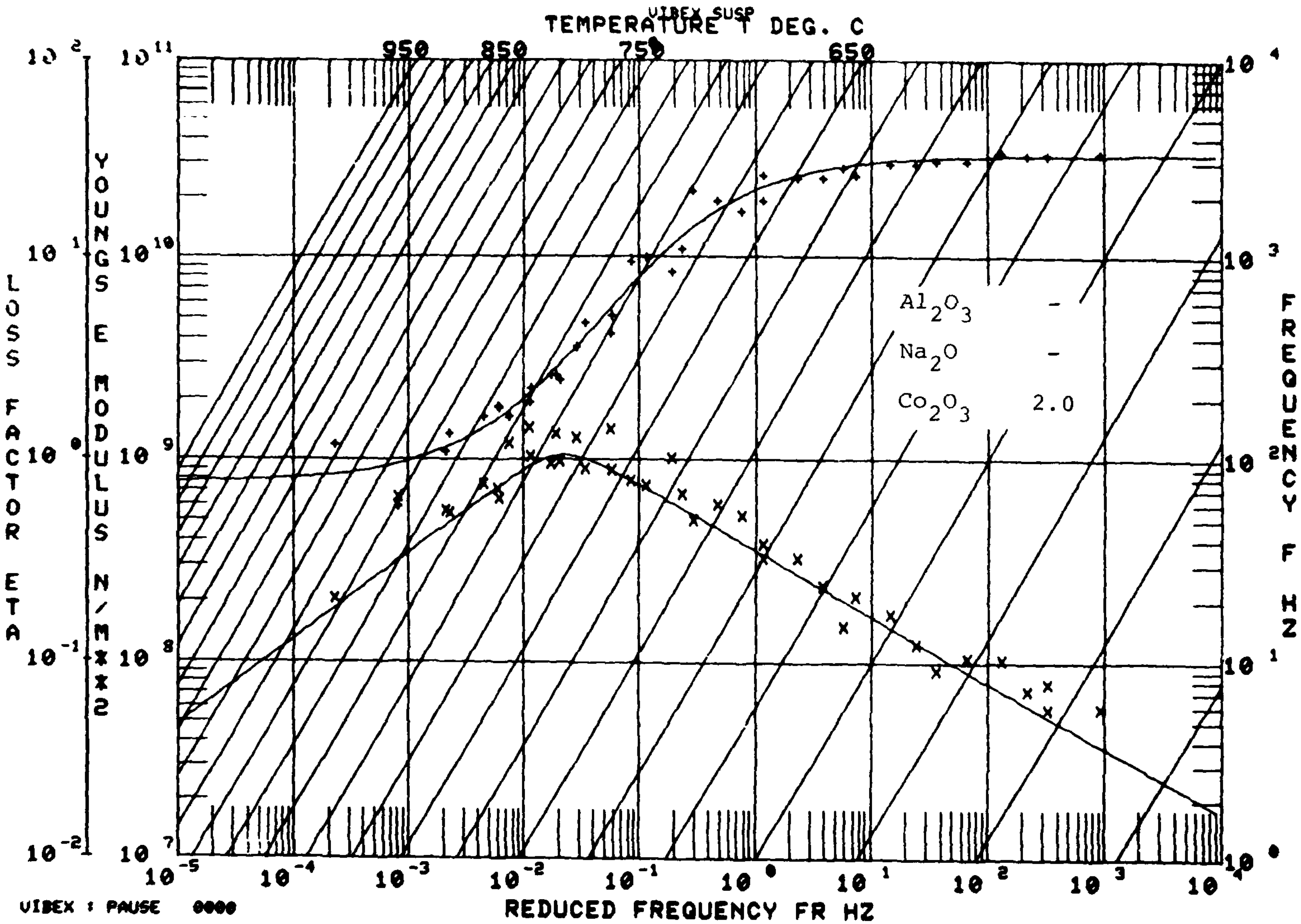

Figure 47. Specimen M5 reduced frequency and temperature nomograph.

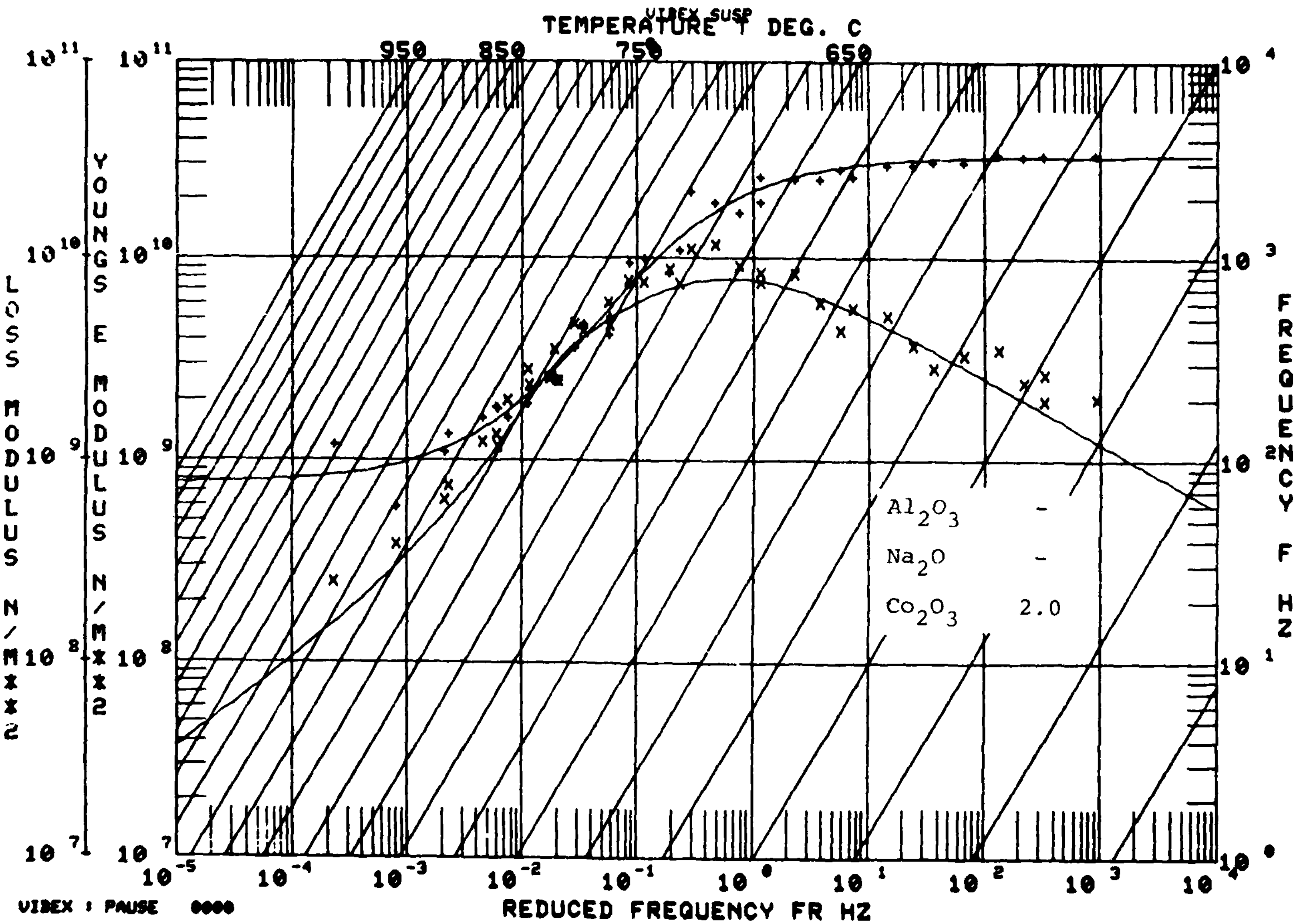

Figure 48. Specimen M5 reduced frequency and temperature nomograph.

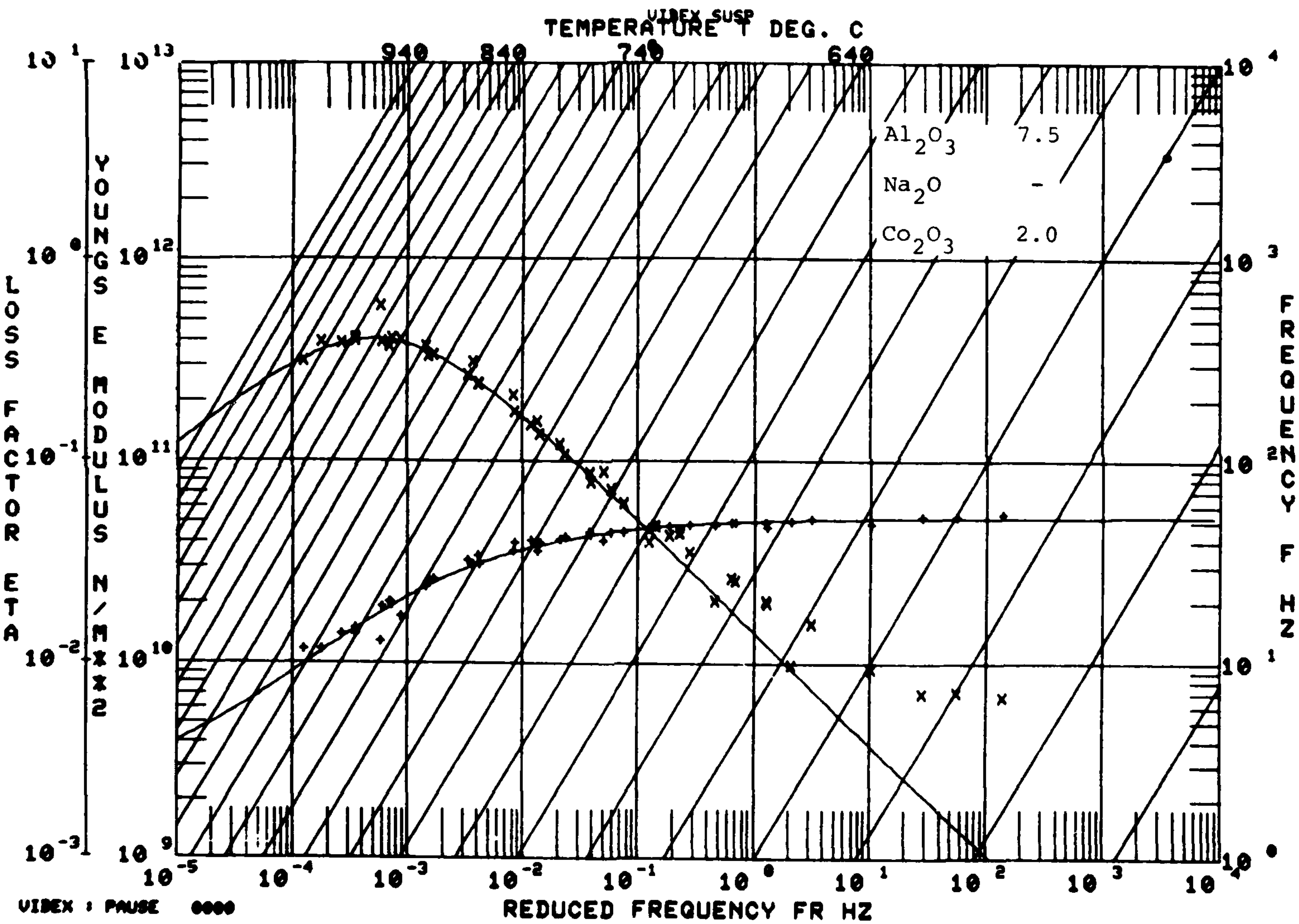

Figure 49. Specimen M27 reduced frequency and temperature nomograph.

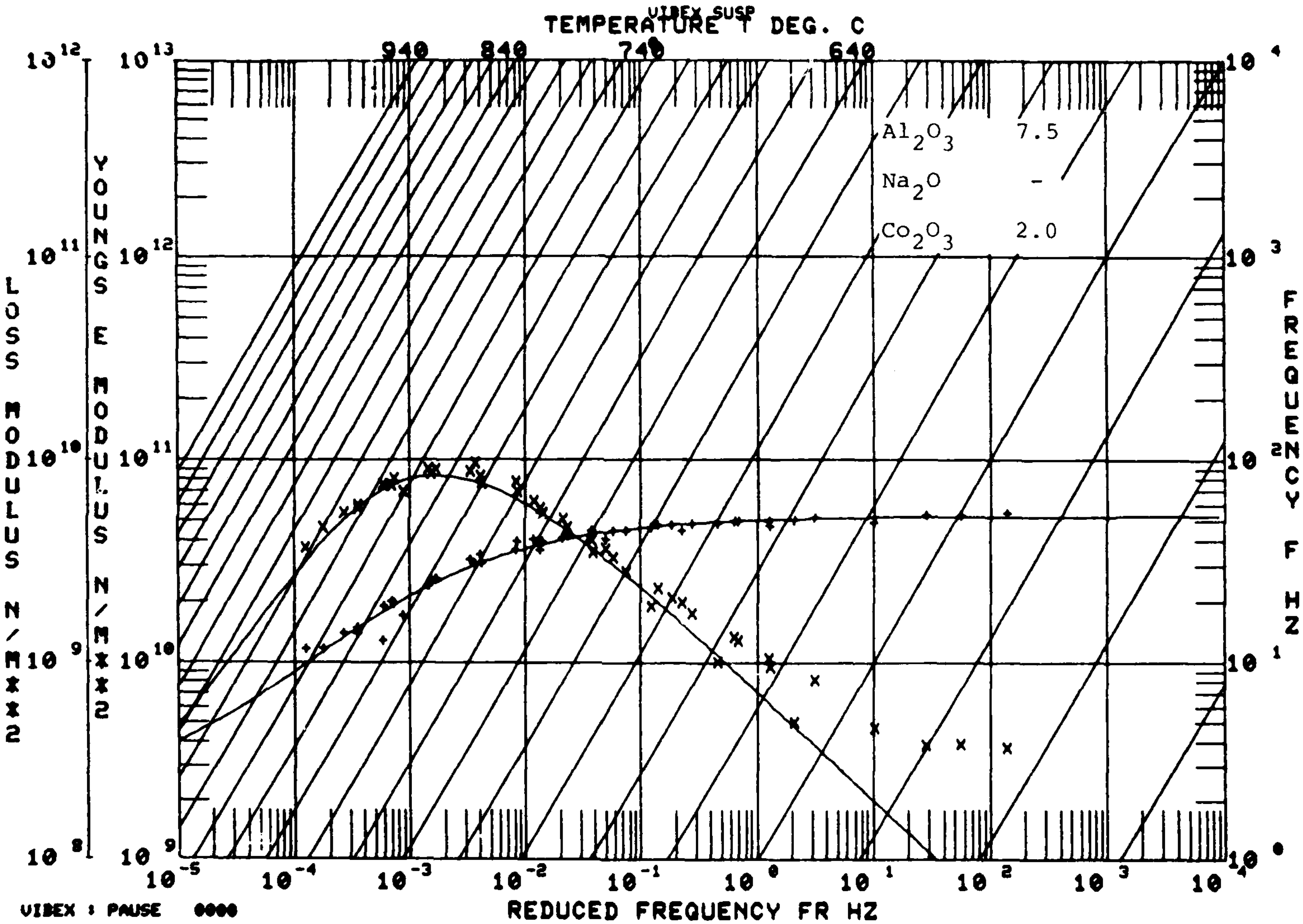

Figure 50. Specimen M27 reduced frequency and temperature nomograph.

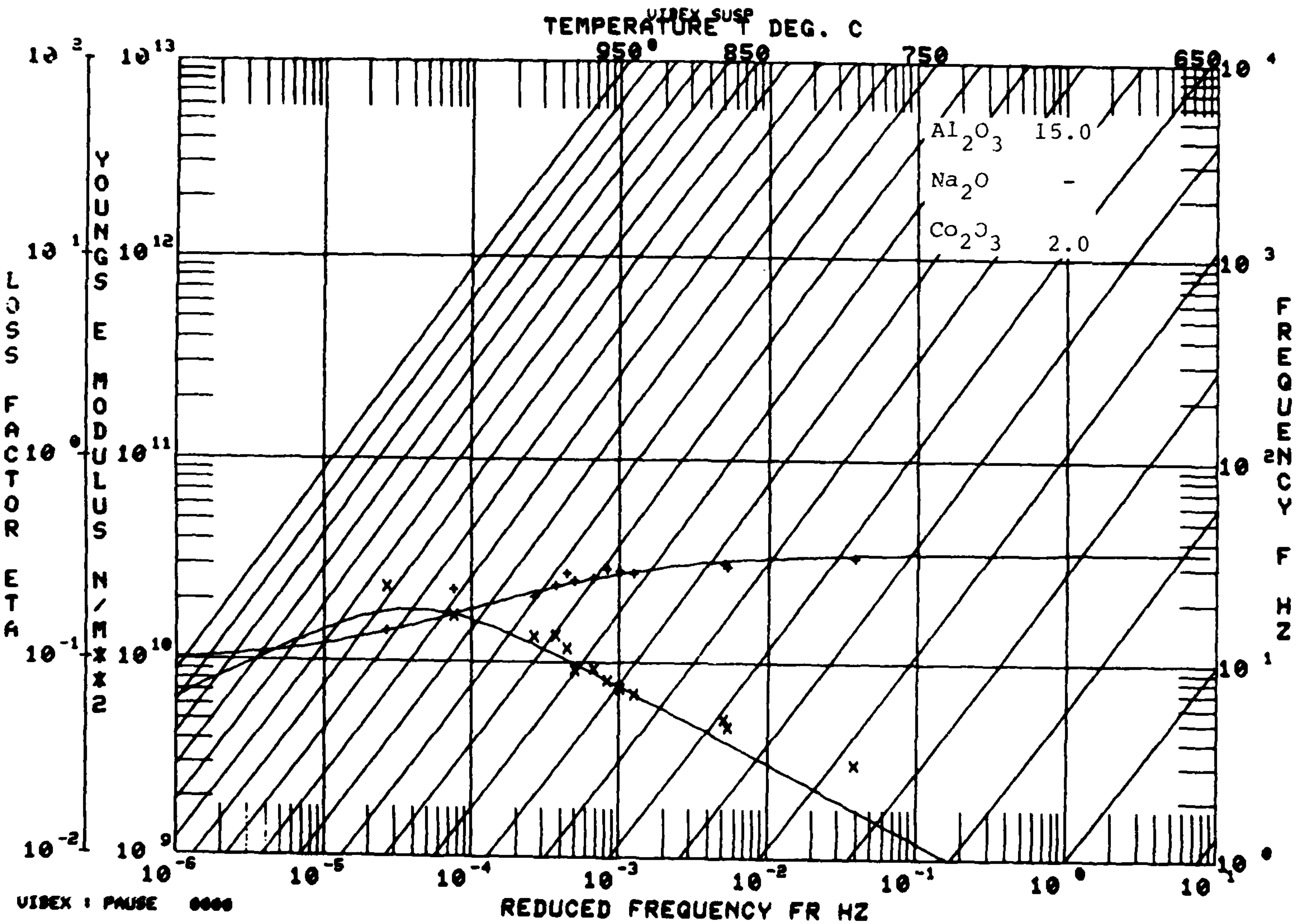

Figure 51. Specimen M41 reduced frequency and temperature nomograph.

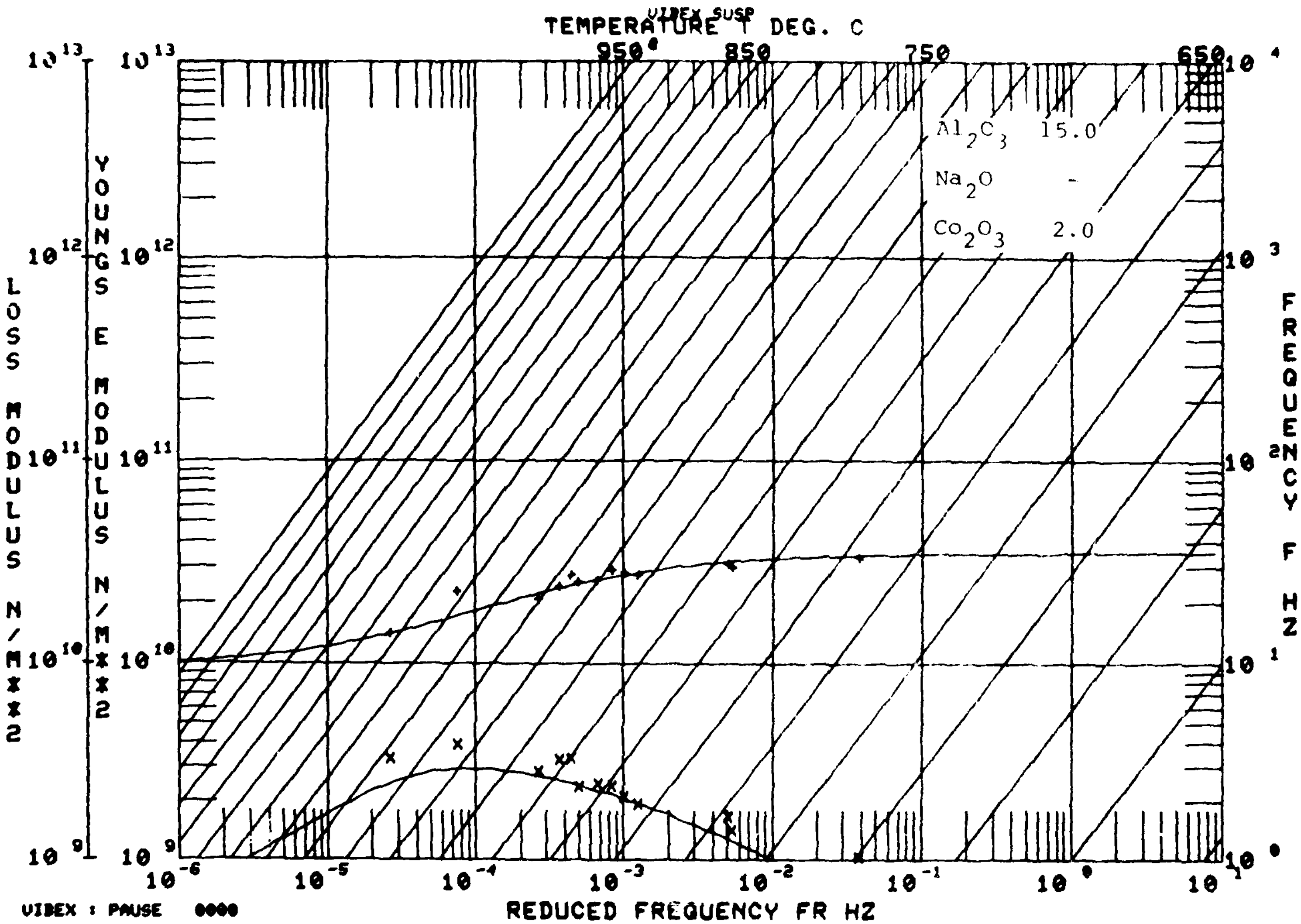

Figure 52. Specimen M41 reduced frequency and temperature nomograph.

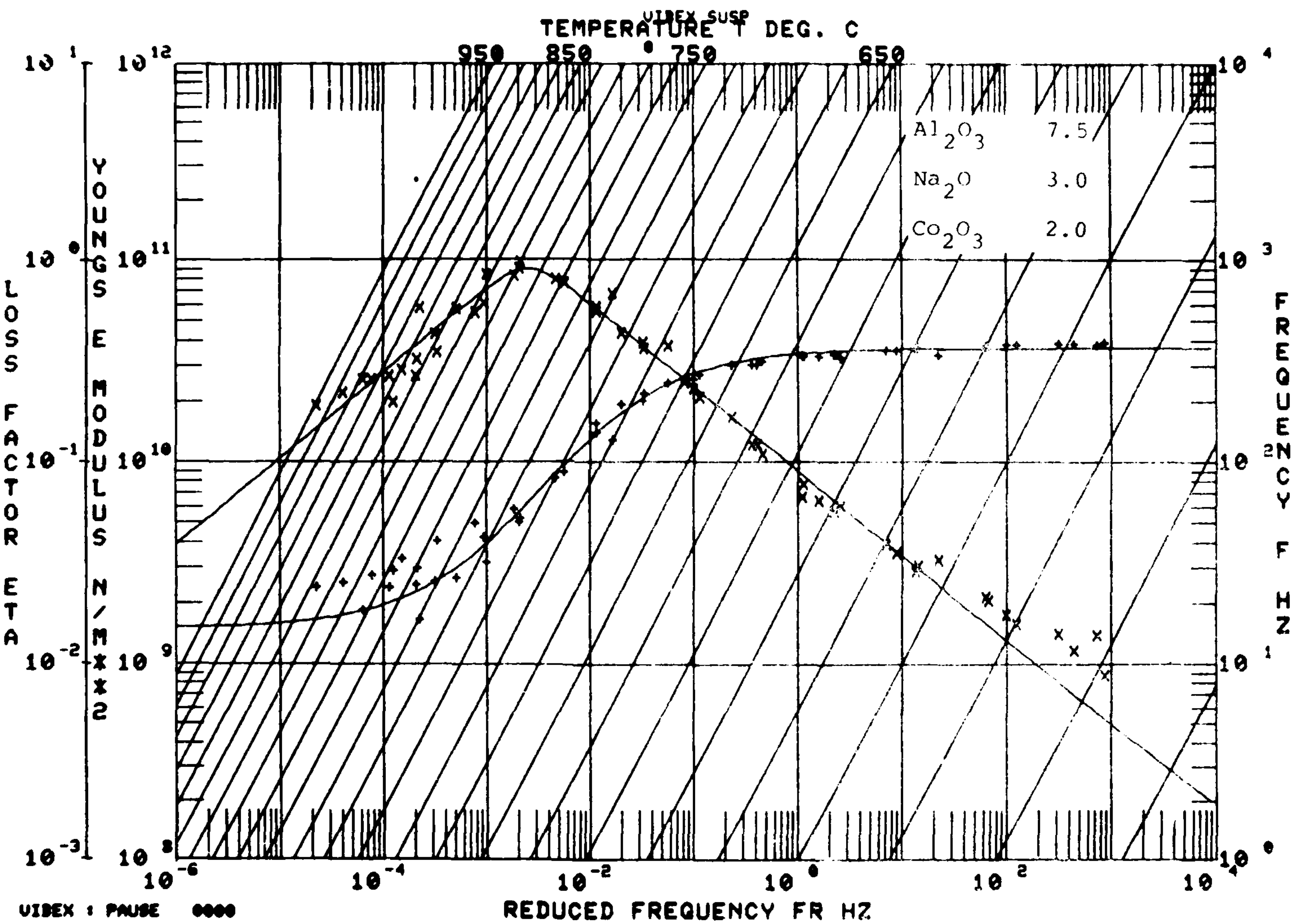

Figure 53. Specimen M31 reduced frequency and temperature nomograph.

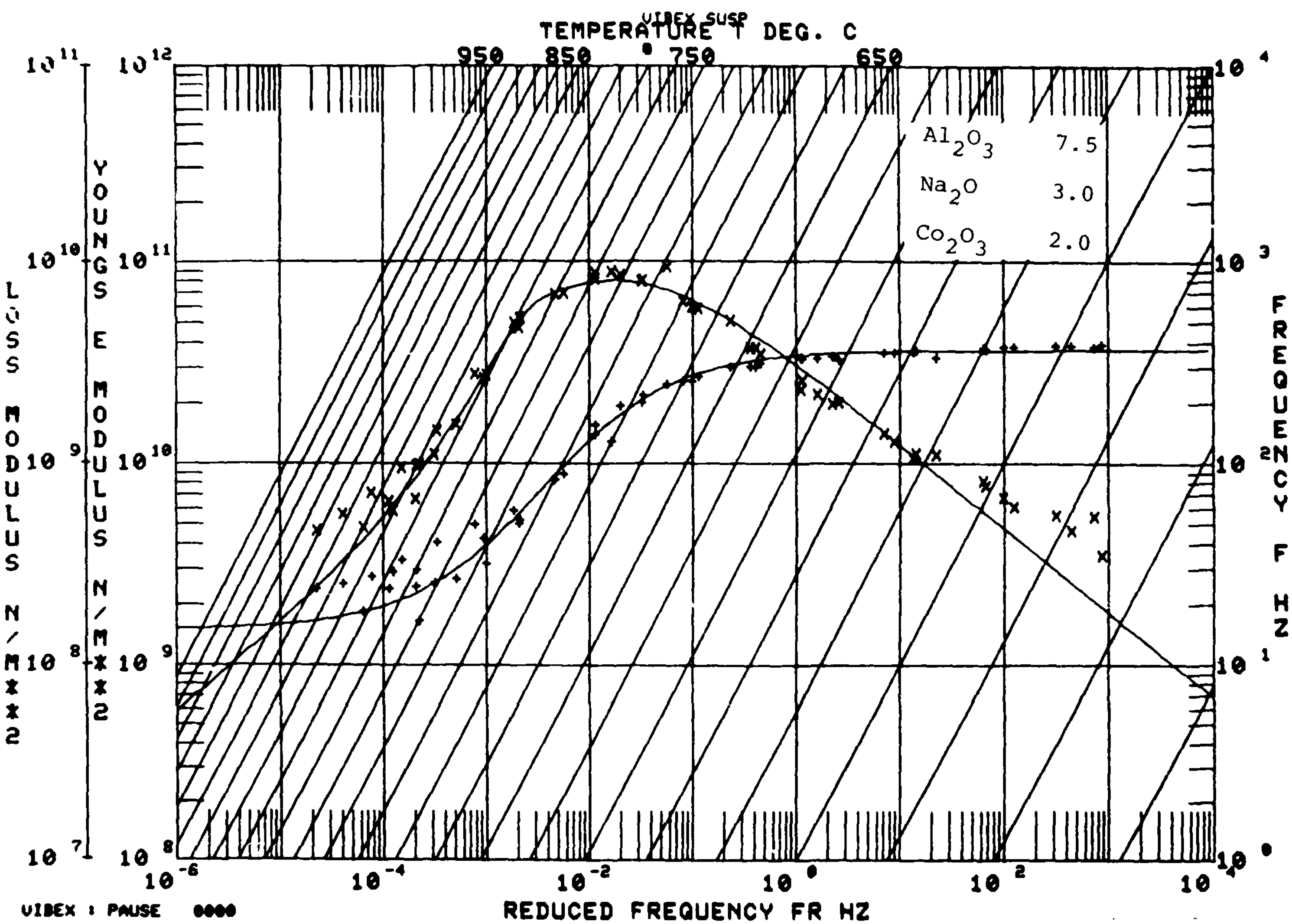

Figure 54. Specimen M31 reduced frequency and temperature nomograph.

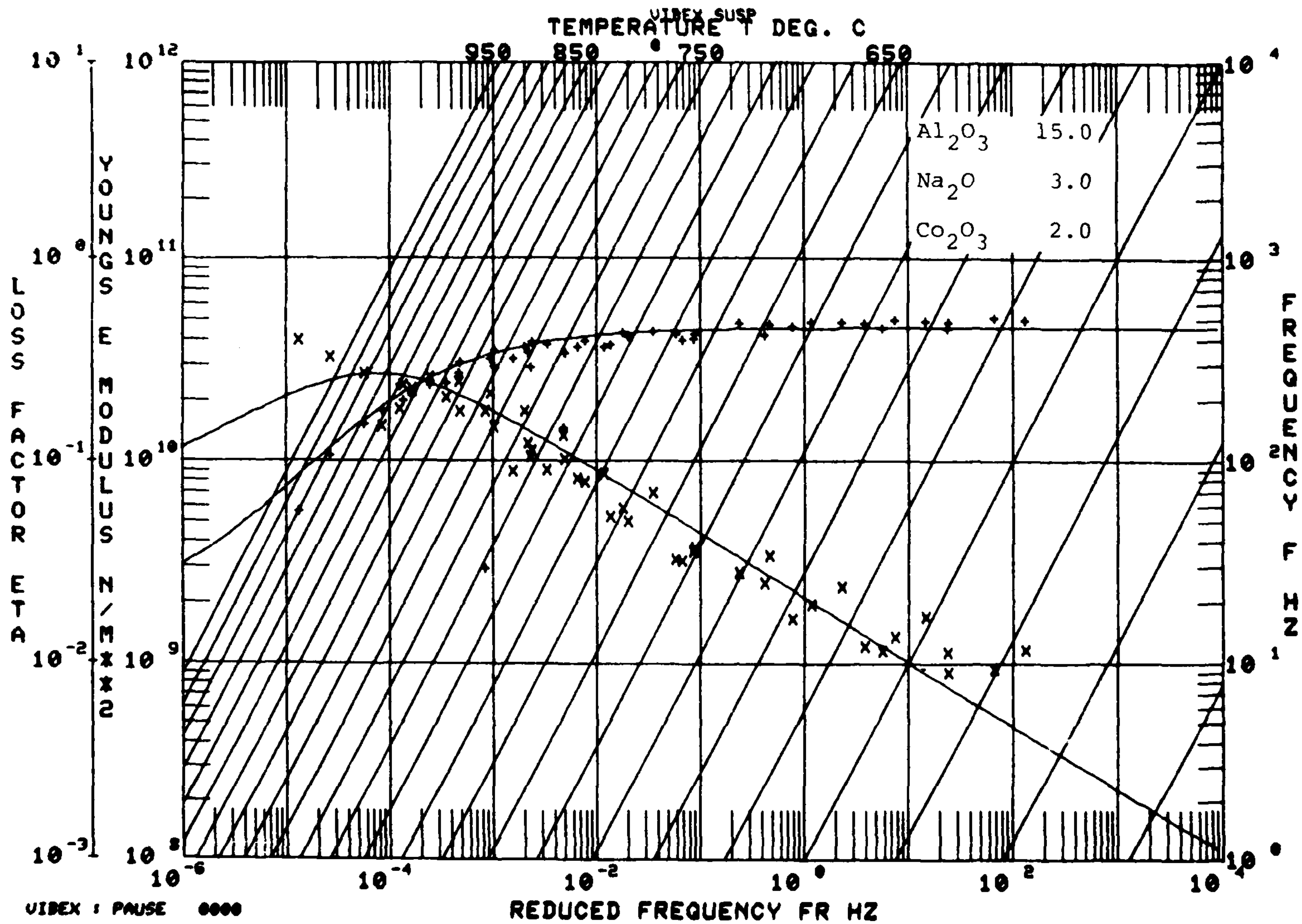

Figure 55. Specimen M4 reduced frequency and temperature nomograph.

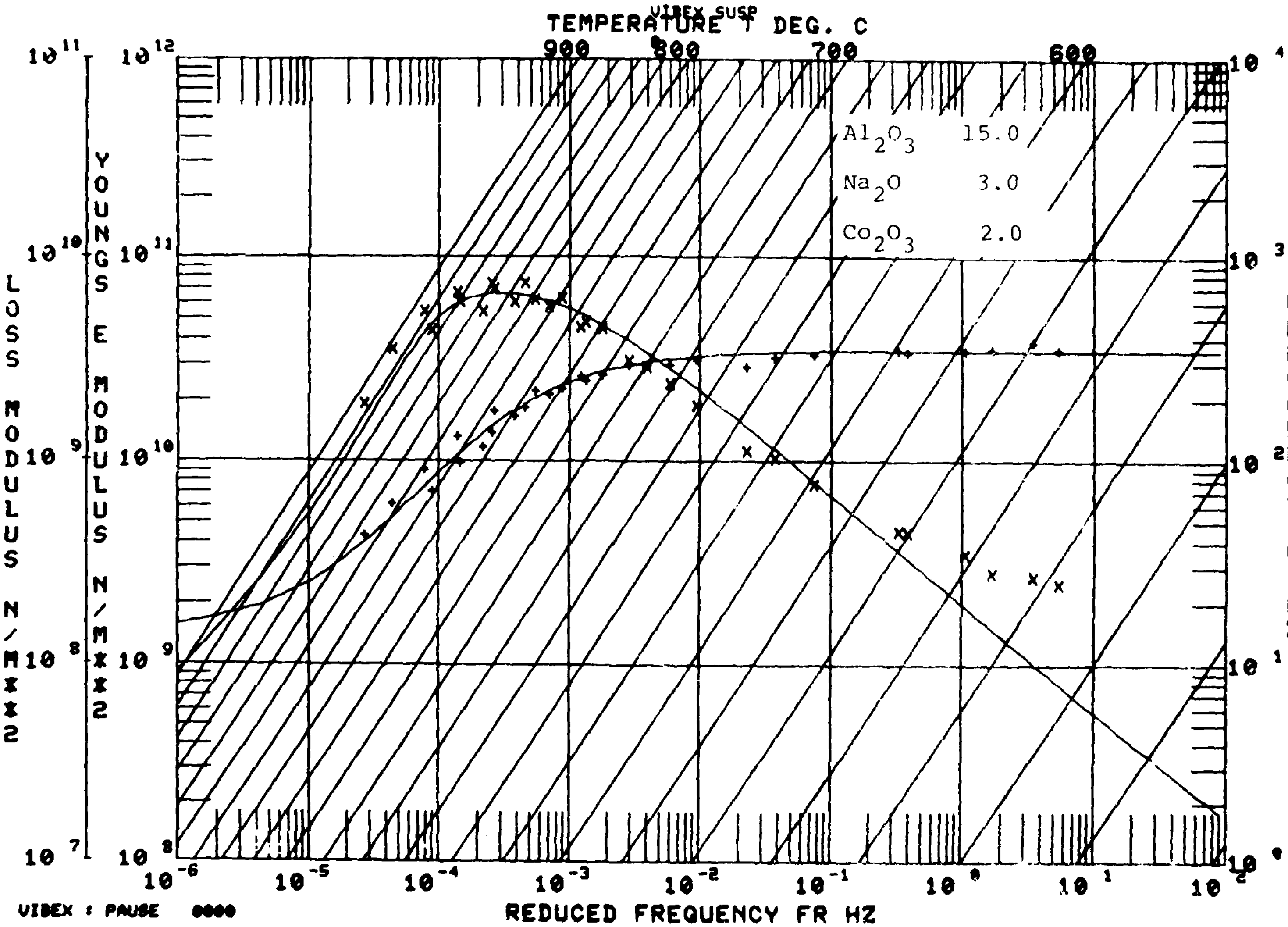

Figure 56. Specimen M4 reduced frequency and temperature nomograph.

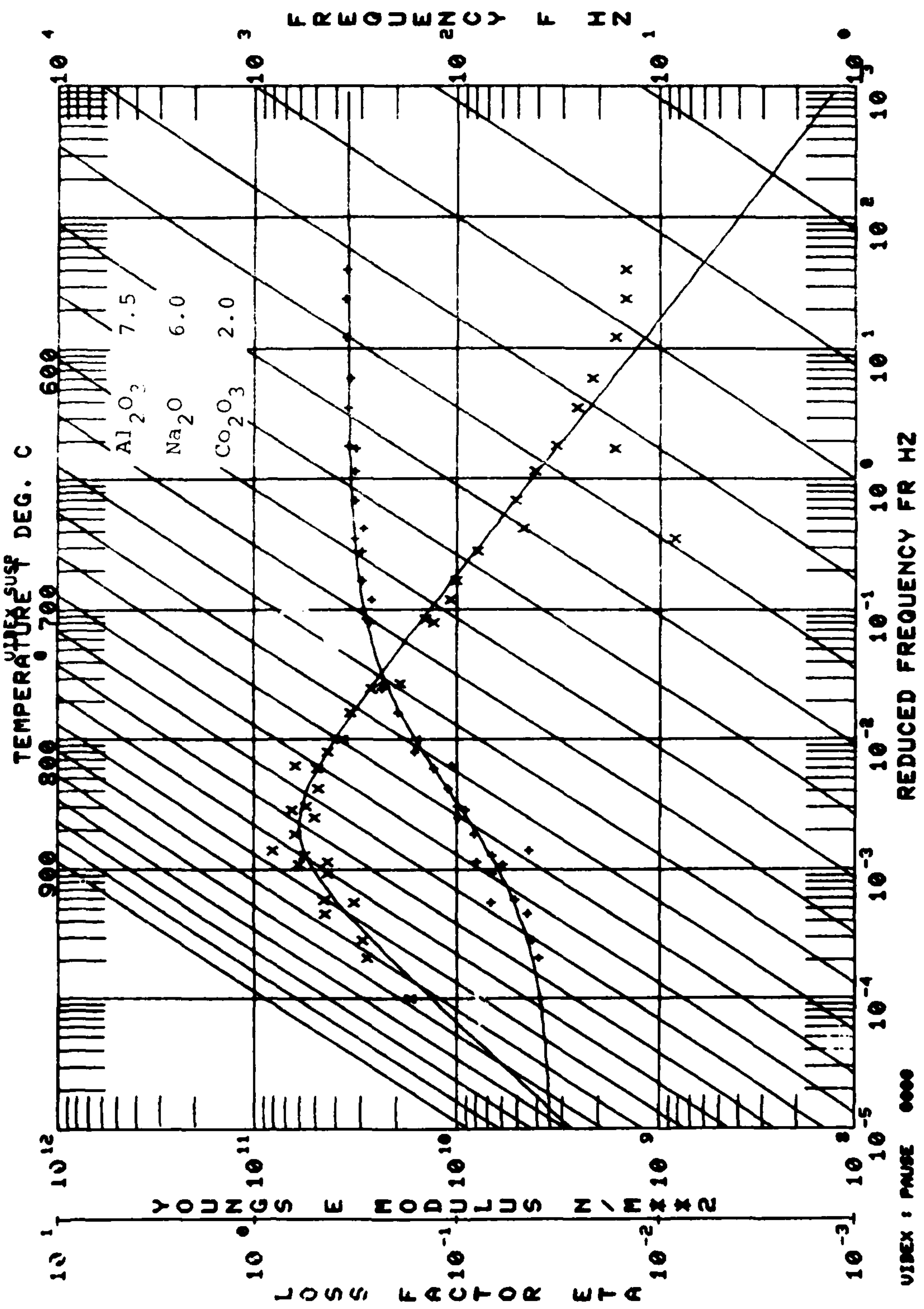

Figure 57. Specimen M45 reduced frequency and temperature nomograph.

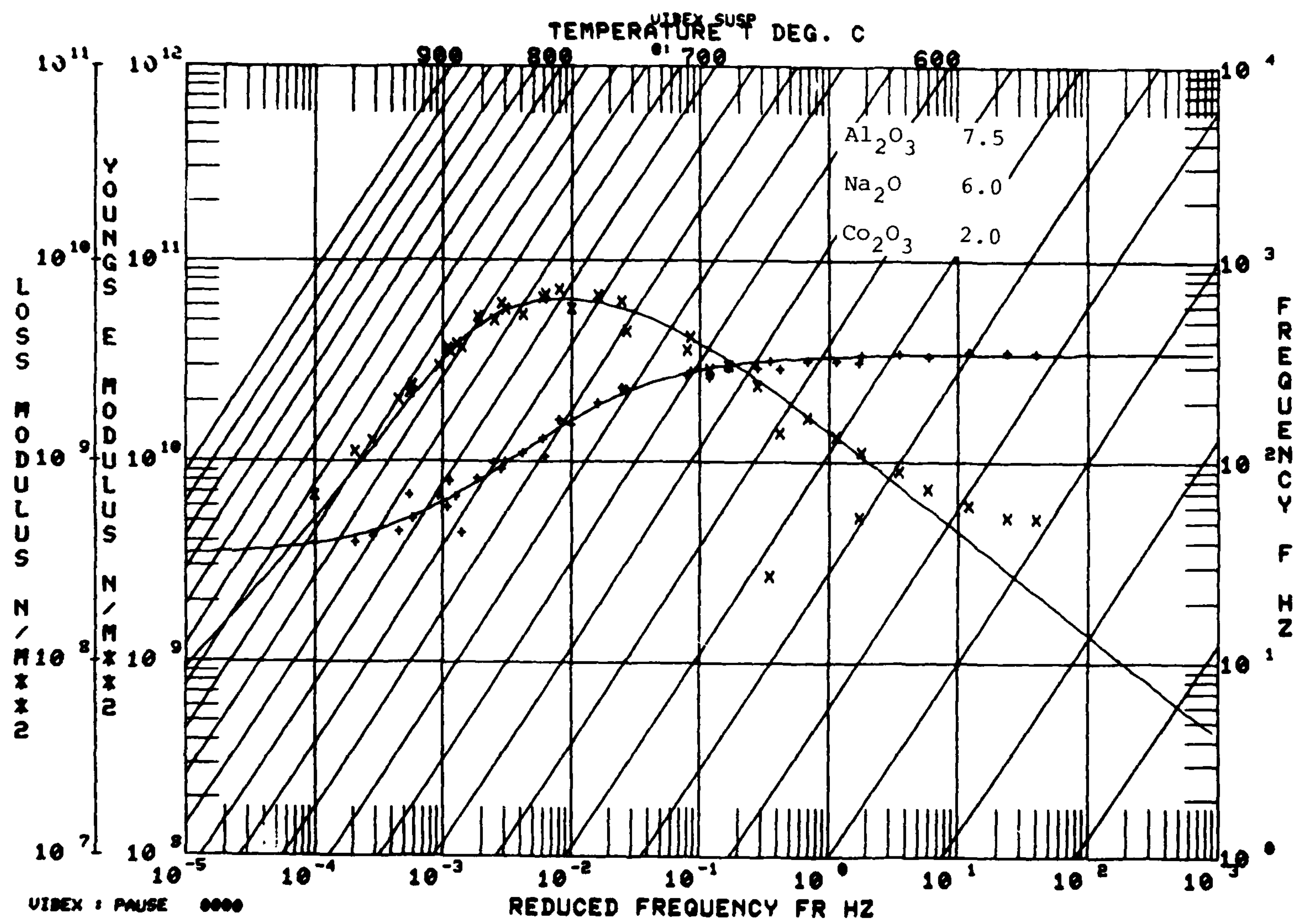

Figure 58. Specimen M45 reduced frequency and temperature nomograph.

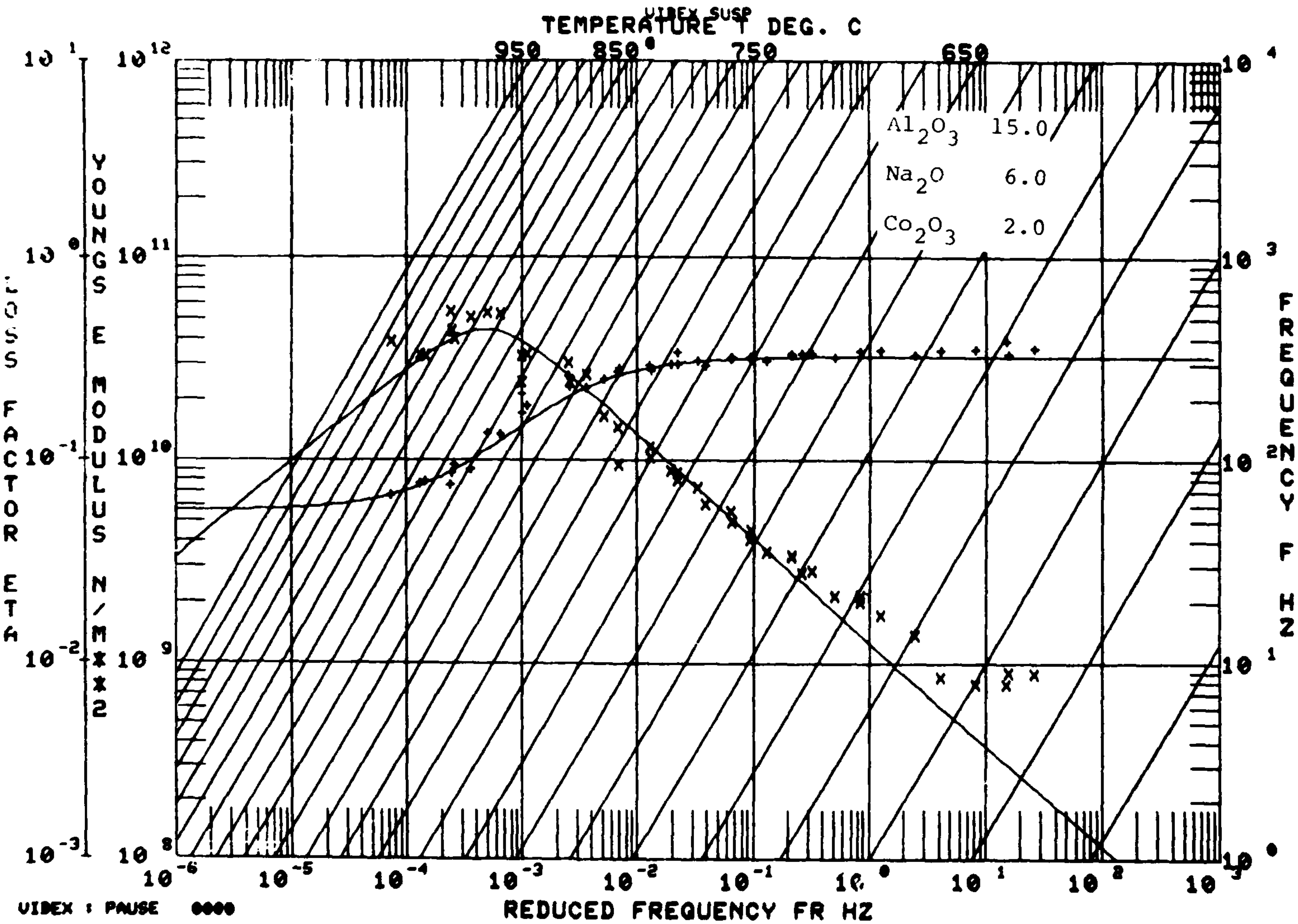

Figure 59. Specimen M46 reduced frequency and temperature nomograph.

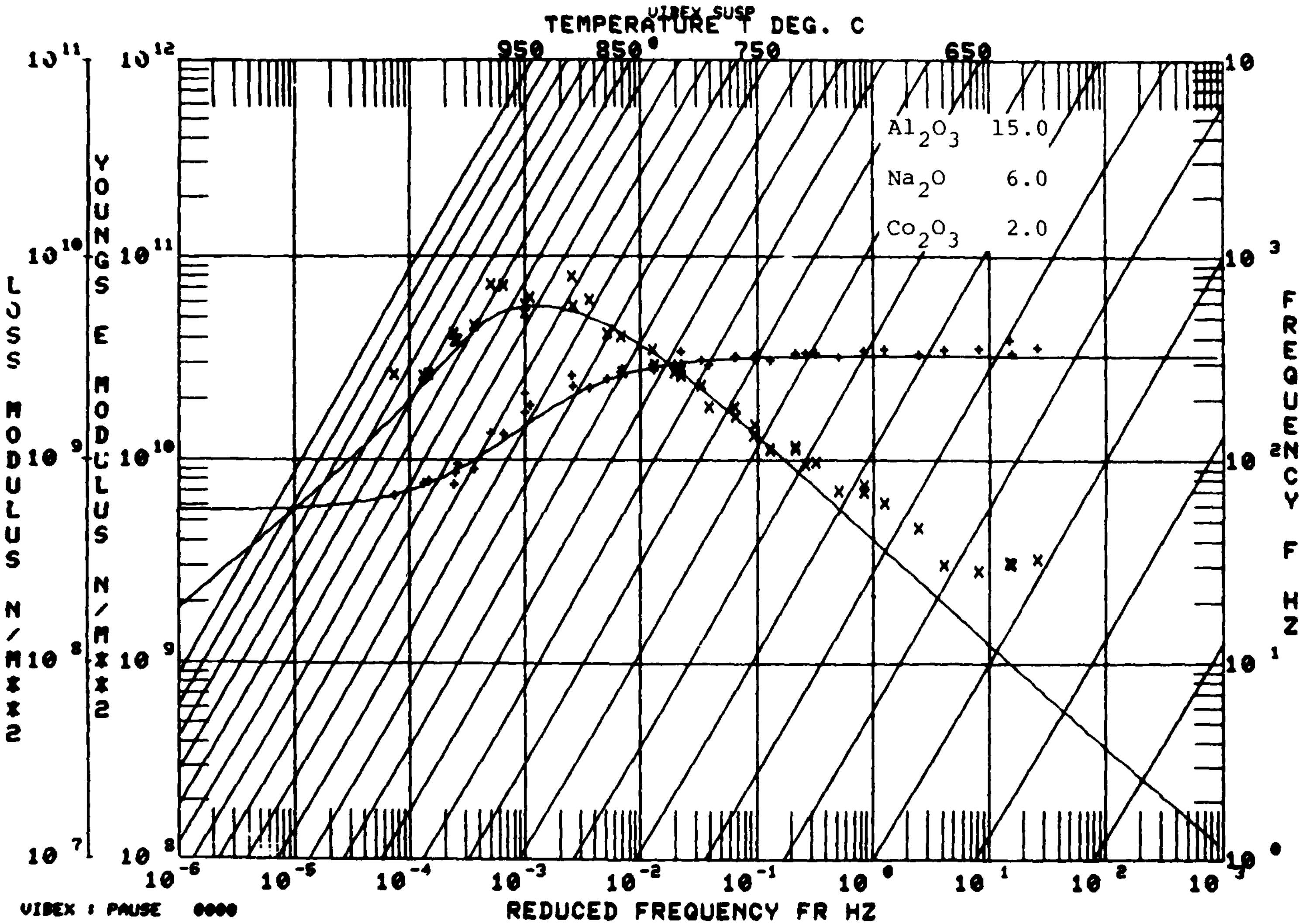

Figure 60. Specimen M46 reduced frequency and temperature nomograph.

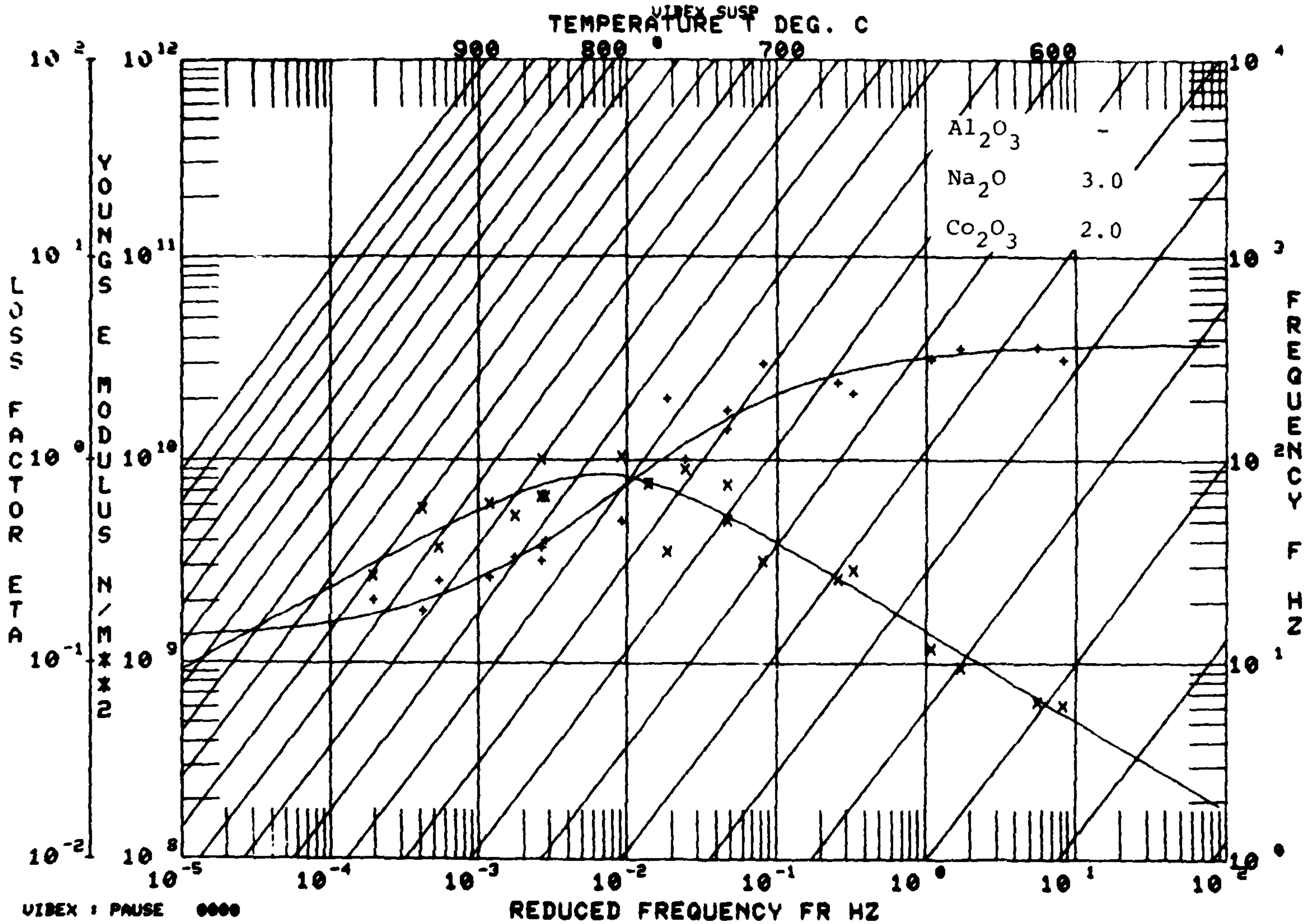

Figure 61. Specimen M6 reduced frequency and temperature nomograph.

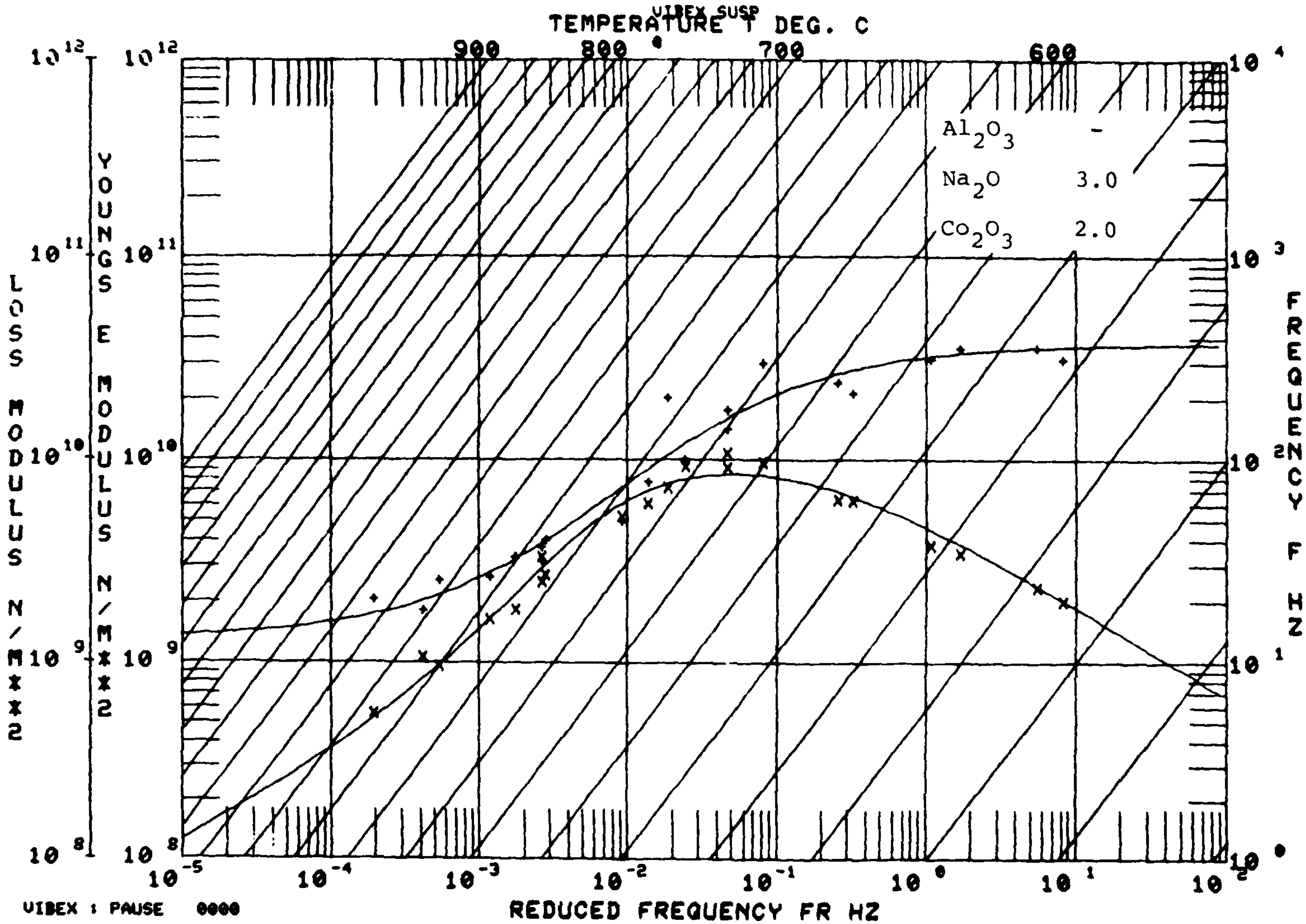

Figure 62. Specimen M6 reduced frequency and temperature nomograph.

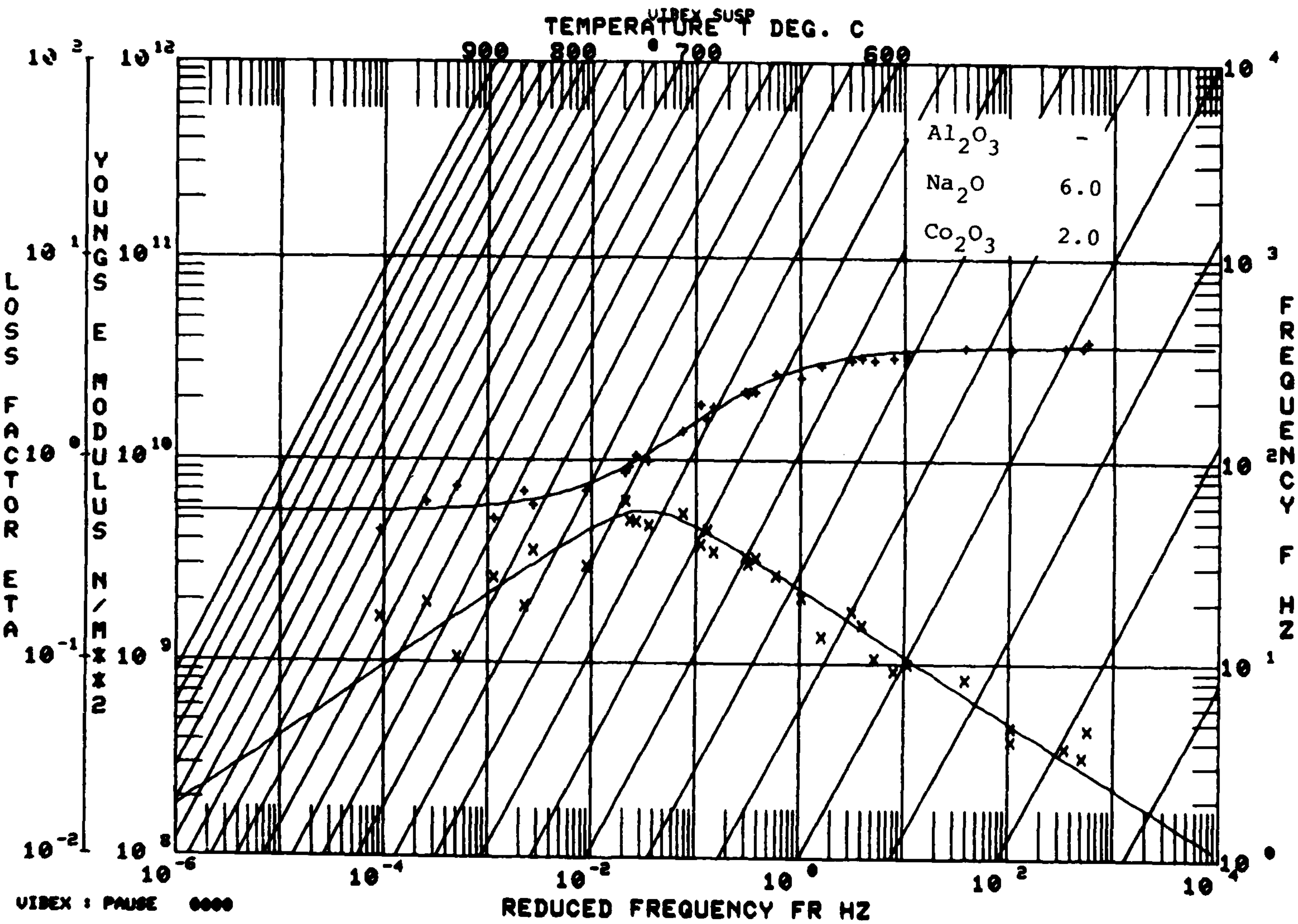

Figure 63. Specimen M7 reduced frequency and temperature nomograph.

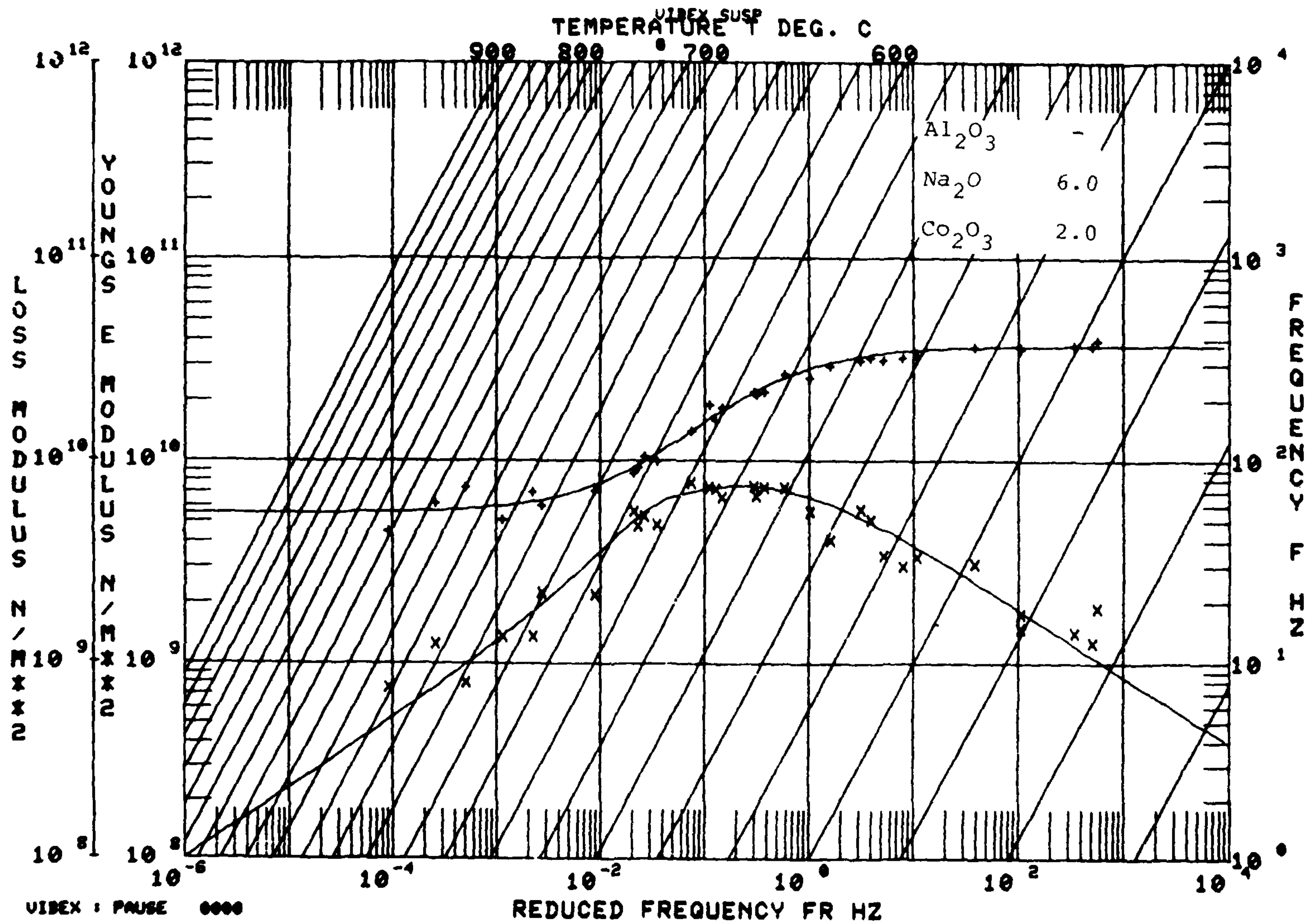

Figure 64. Specimen M7 reduced frequency and temperature nomograph.

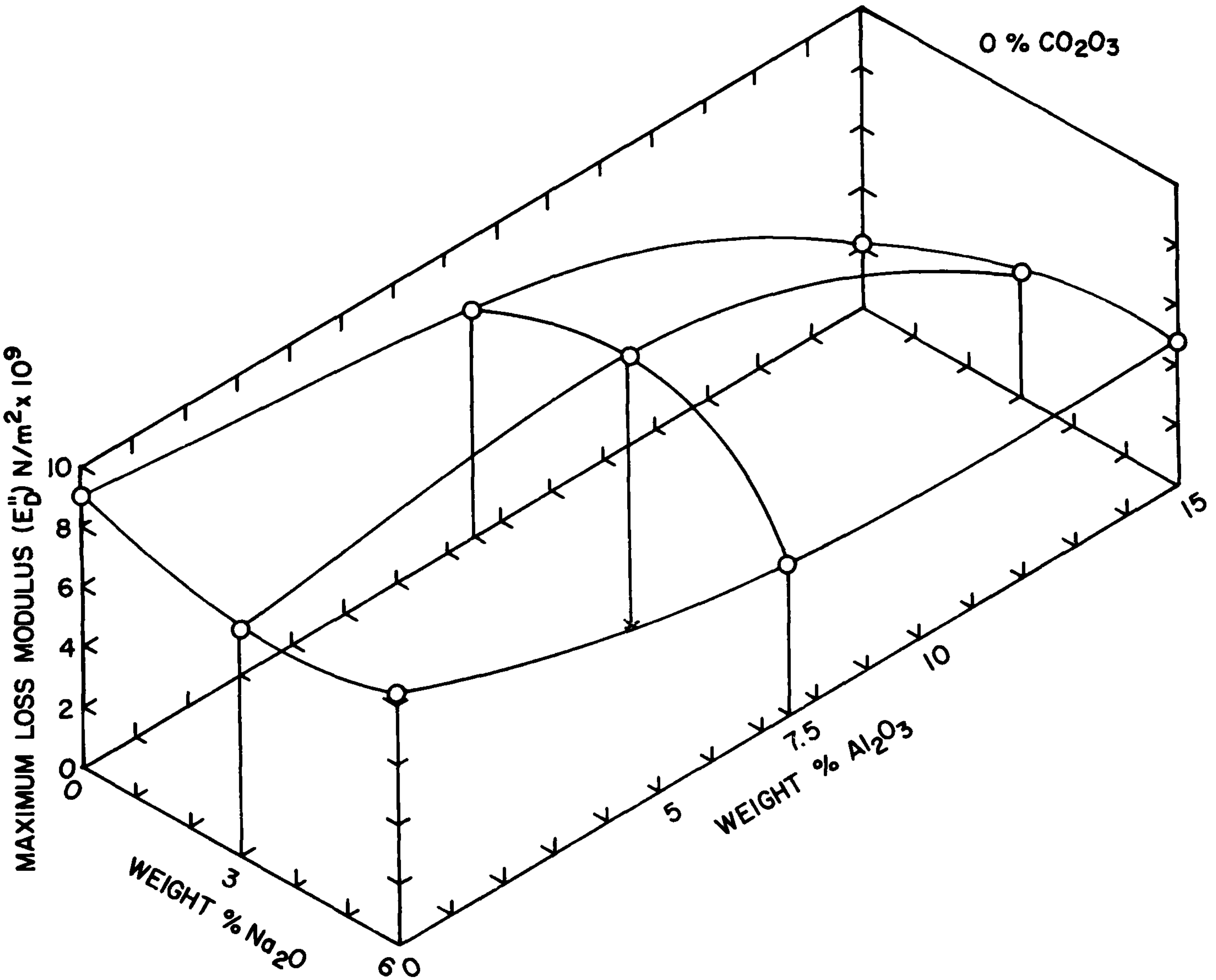

Figure 65. Maximum Loss Modulus Versus Al_2O_3 and Na_2O Additions to Corning 0010 Glass with 0 w/o Co_2O_3.

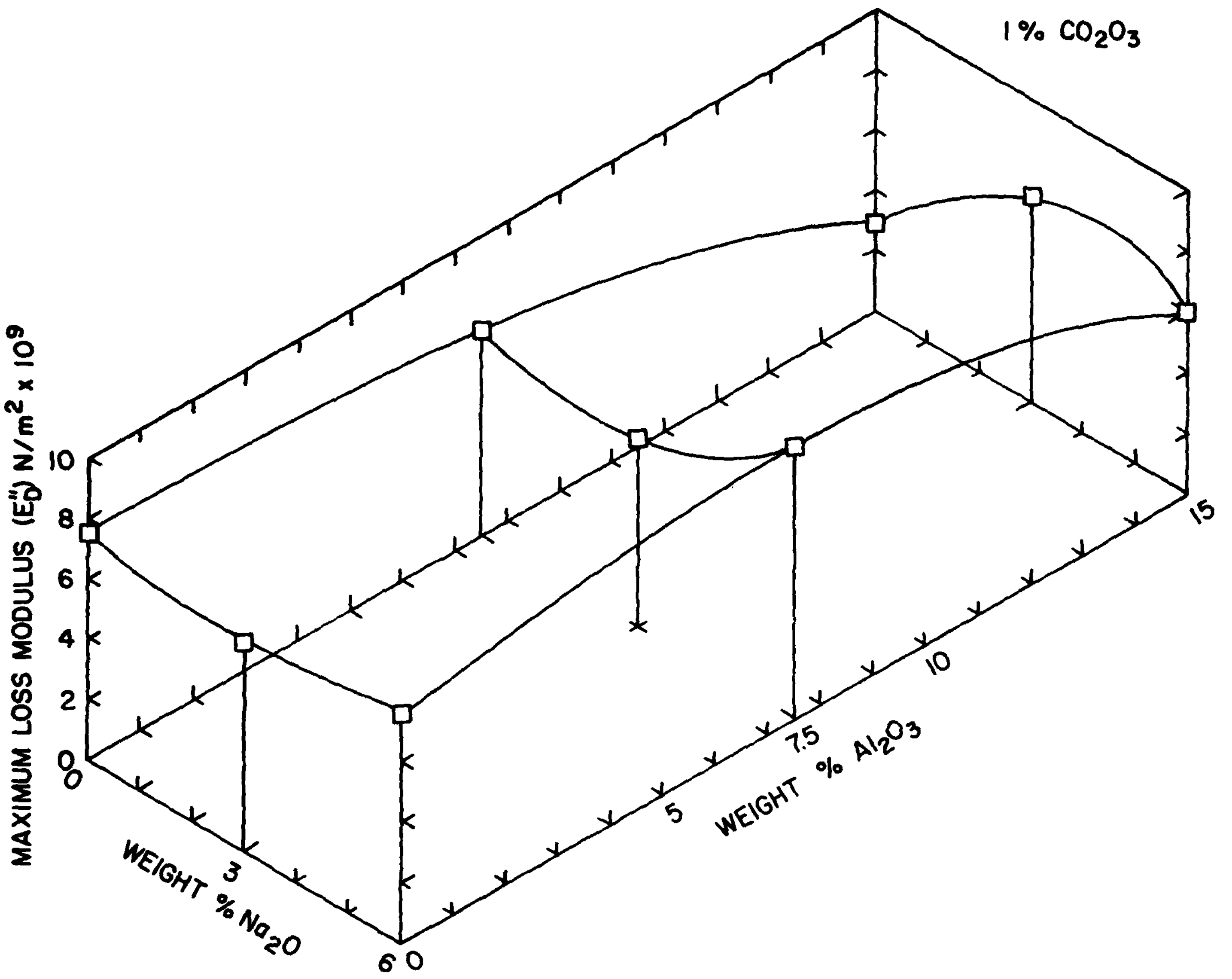

Figure 66. Maximum Loss Modulus Versus Al_2O_3 and Na_2O Additions to Corning 0010 Glass with 1.0 w/o Co_2O_3.

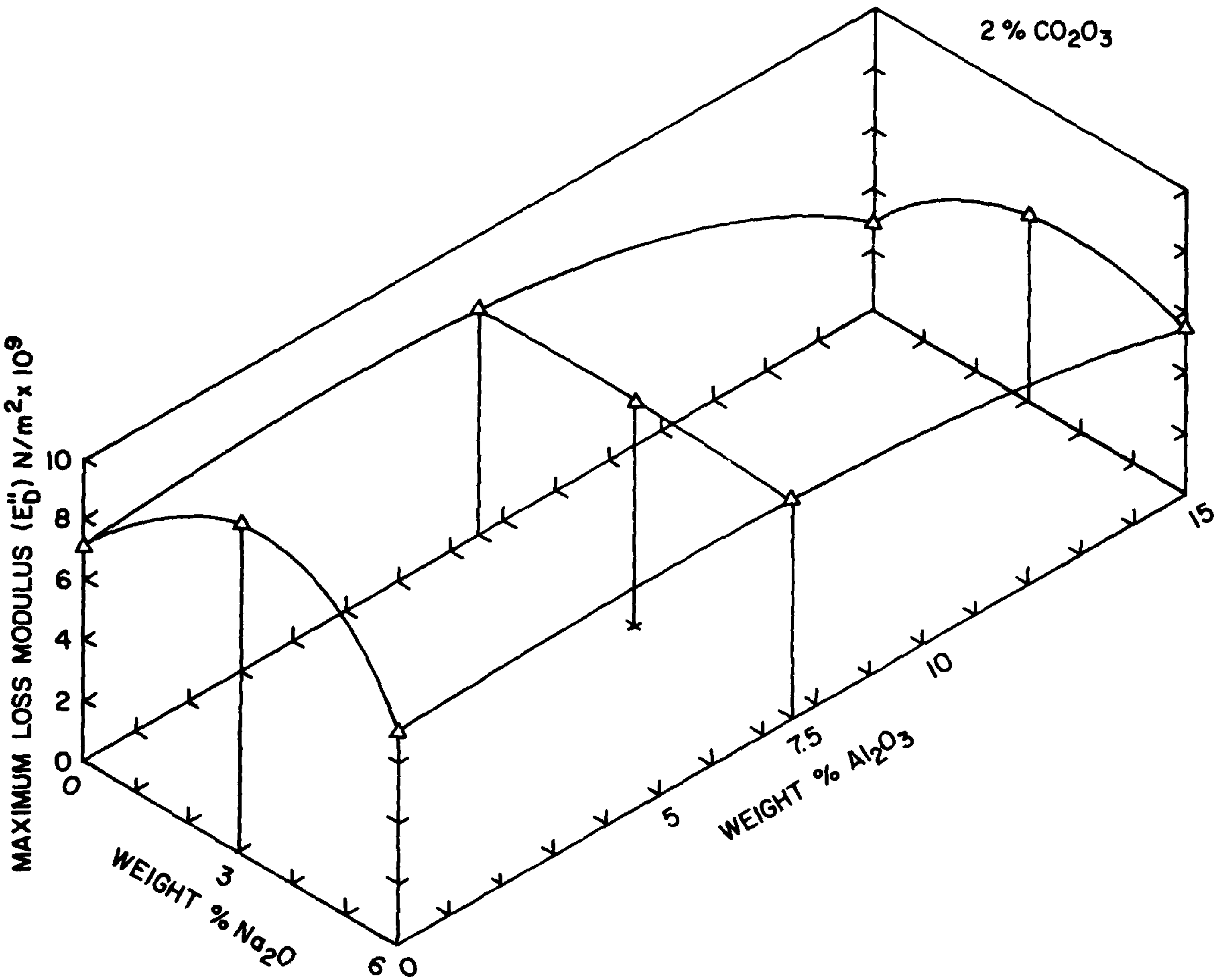

Figure 67. Maximum Loss Modulus Versus Al_2O_3 and Na_2O Additions to Corning 0010 Glass with 2.0 w/o Co_2O_3.

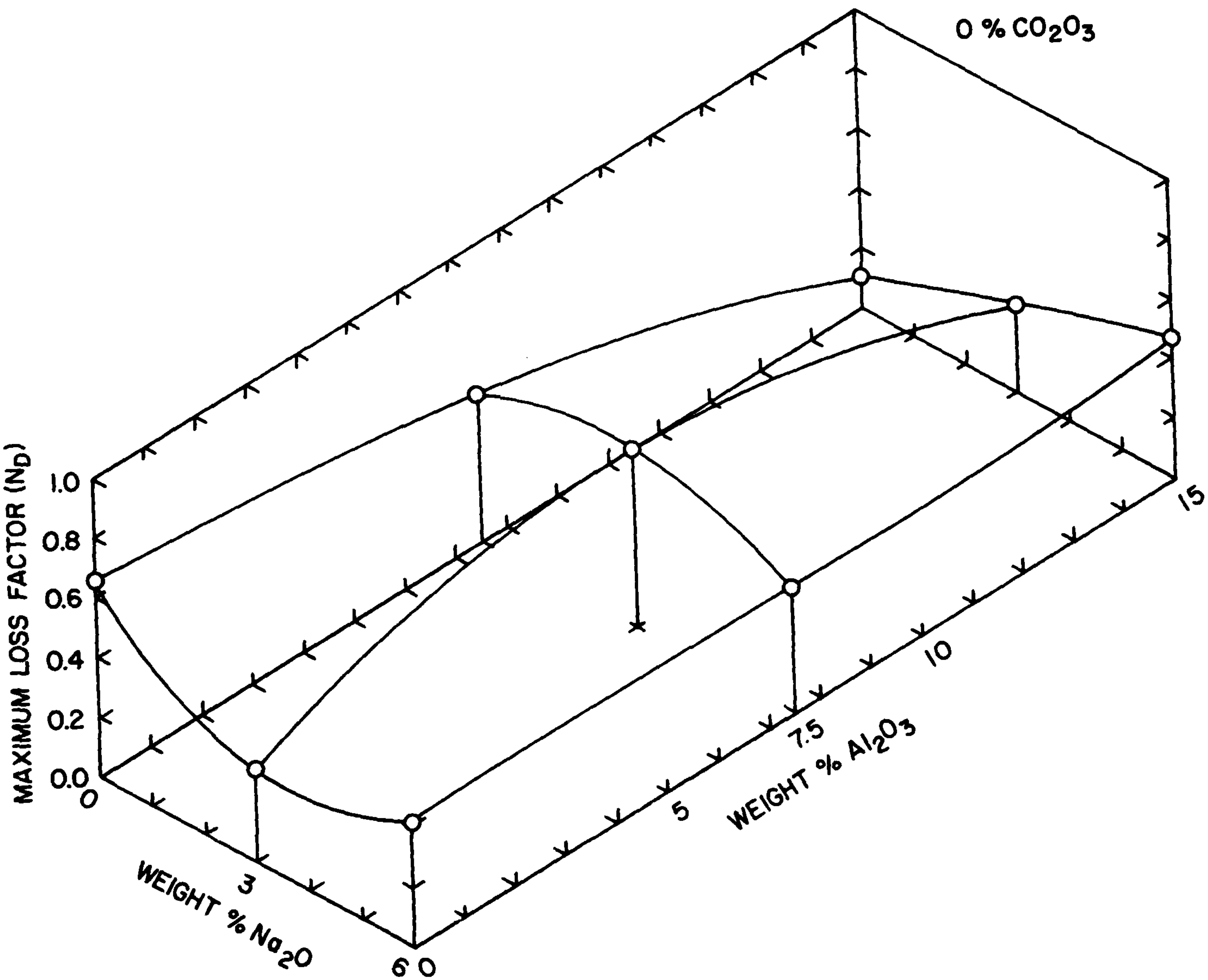

Figure 68. Maximum Loss Factor Versus Al_2O_3 and Na_2O Additions to Corning 0010 Glass with 0 w/o Co_2O_3.

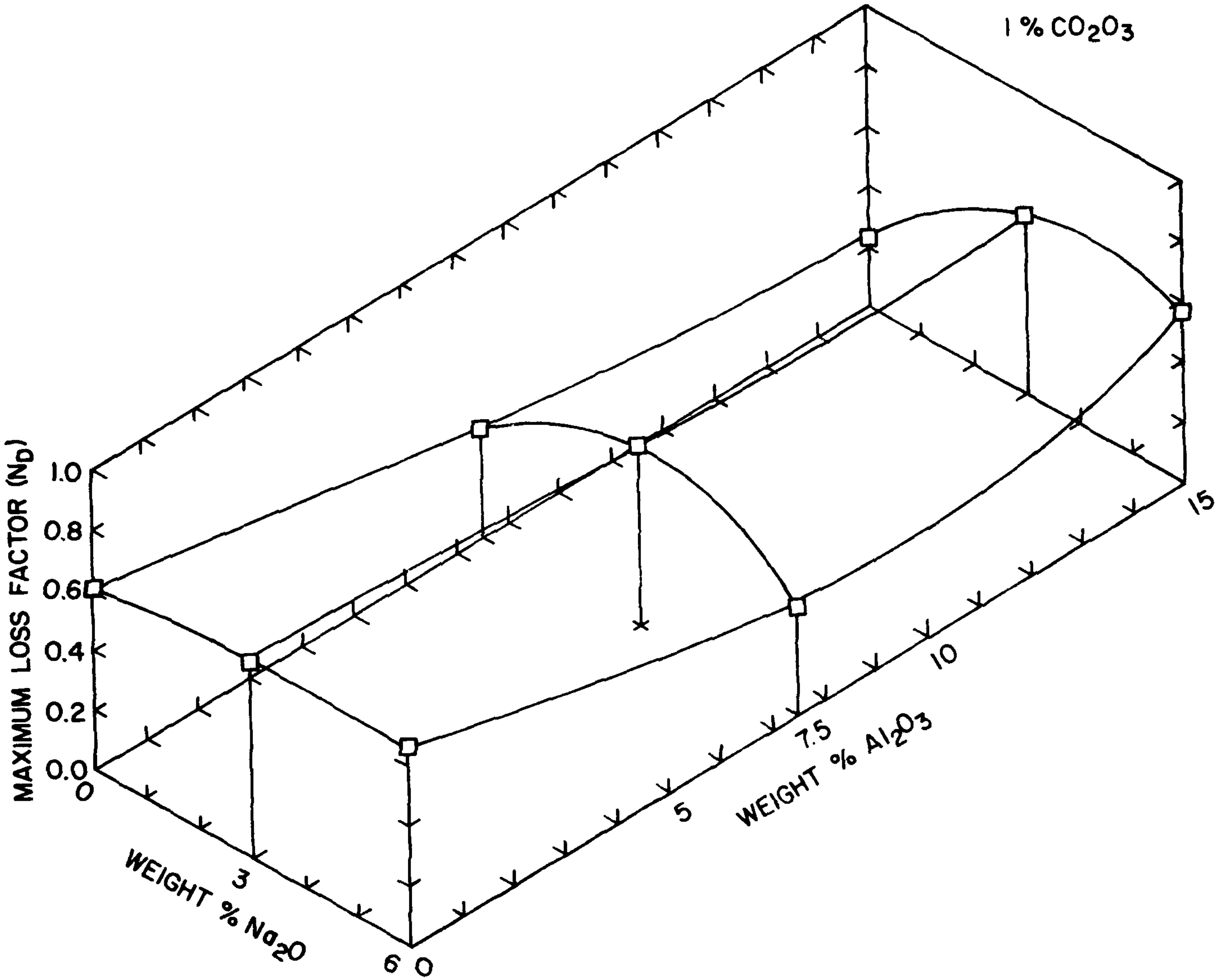

Figure 69. Maximum Loss Factor Versus Al_2O_3 and Na_2O Additions to Corning 0010 Glass with 1 w/o Co_2O_3.

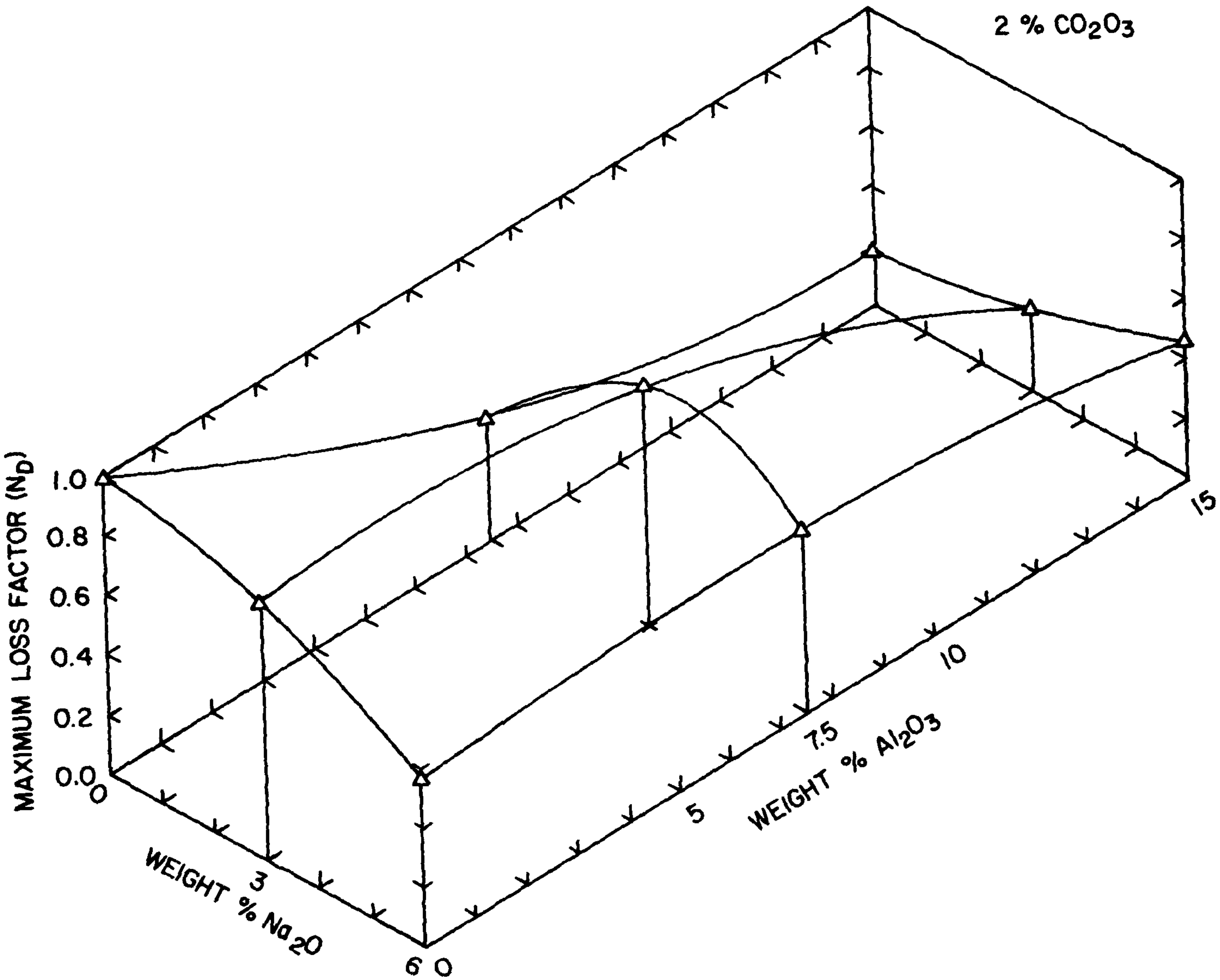

Figure 70. Maximum Loss Factor Versus Al_2O_3 and Na_2O Additions to Corning 0010 Glass with 2 w/o Co_2O_3.

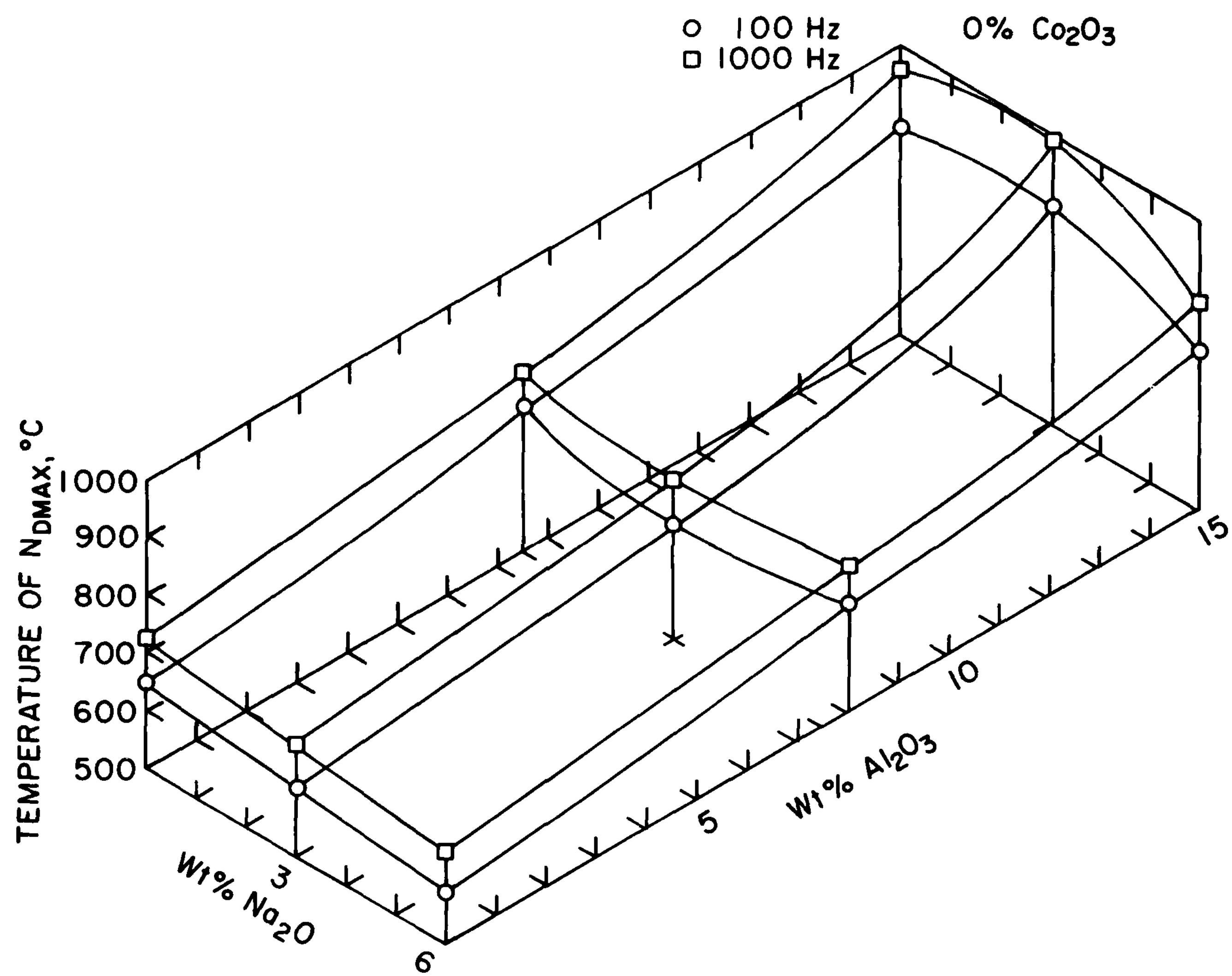

Figure 71. Variation of Temperature of Maximum Loss Factor with Additions of Al_2O_3 and Na_2O to Corning 0010 Glass with 0 w/o Co_2O_3 (at 100 and 1000^3Hz).

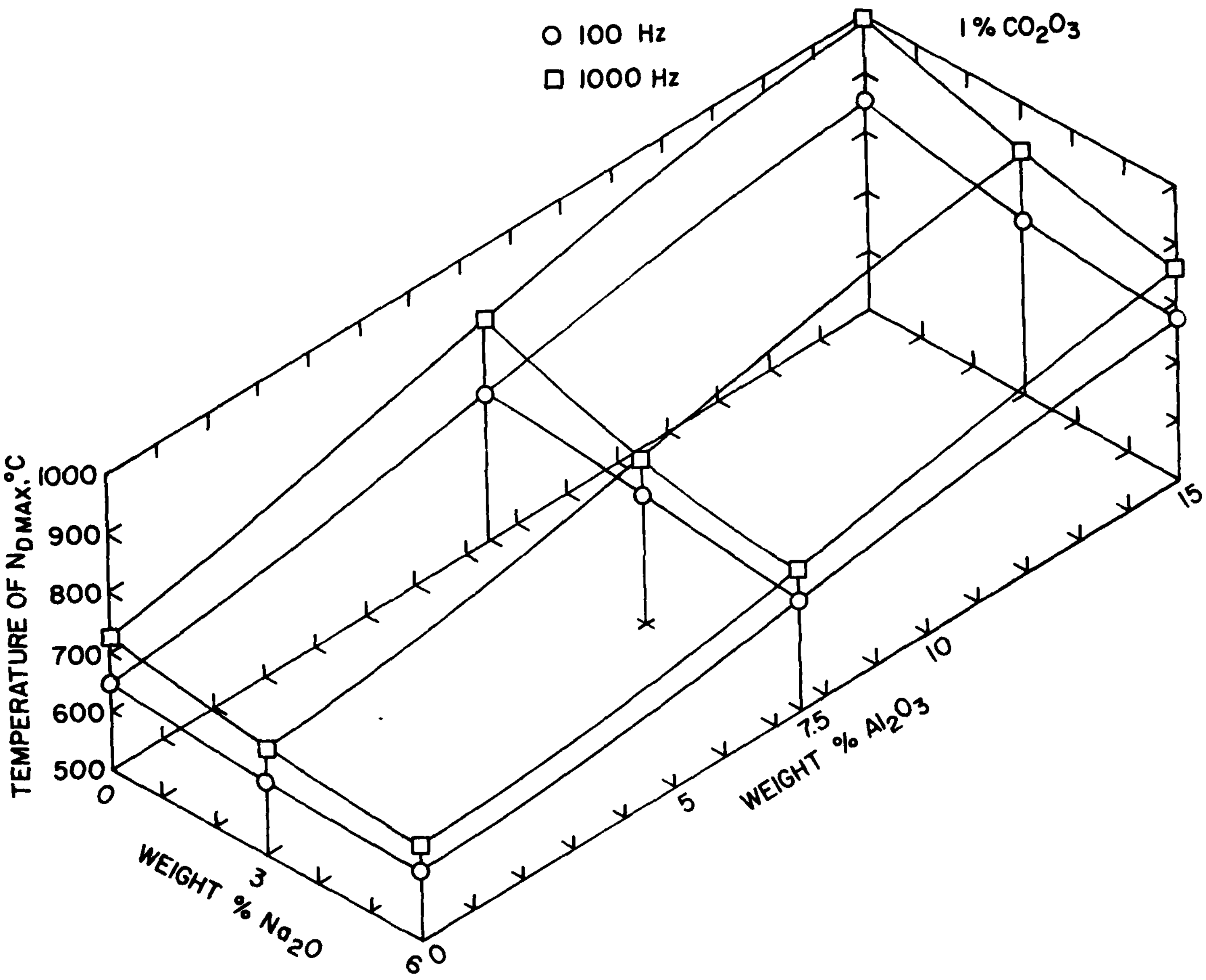

Figure 72. Variation of Temperature of Maximum Loss Factor with Additions of Al_2O_3 and Na_2O to Corning 0010 Glass with 1 w/o Co_2O_3 (at 100 and 1000 Hz).

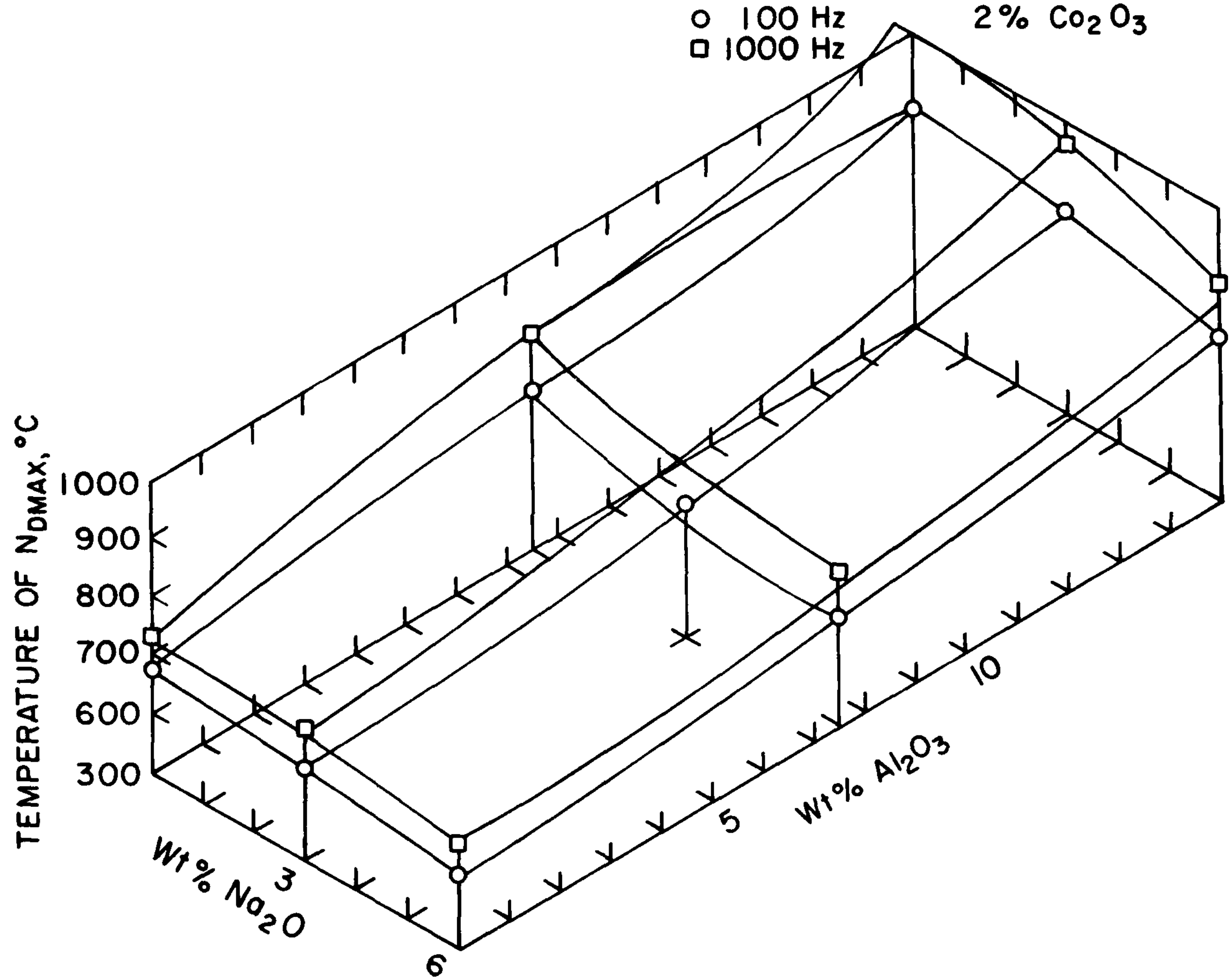

Figure 73. Variation of Temperature of Maximum Loss Factor with Additions of Al_2O_3 and Na_2O to Corning 0010 Glass with 2 w/o Co_2O_3 (at 100 and 1000 Hz).

additions of Na_2O lower the temperature of peak damping. The addition of Co_2O_3 increased the temperature of peak loss factor. The magnitude of the loss modulus decreased with increasing percent addition whereas the loss factor first decreased and then increased.

In general, the additions of the three oxides affected the vibration damping properties in the manner expected. The addition of Al_2O_3, and its intermediate, is known to increase the temperature at which a silicate glass will reach a specified viscosity. If, as assumed, the peak damping occurs above the glass transition temperature range, one would expect an addition that increased the viscosity of the glass would also increase the temperature of peak damping. Conversely, the addition of a modifier like Na_2O would be expected to decrease the temperature of peak damping. However, the effect of adding a heavy metal ion like Co is difficult to ascertain. The Co is believed to react with the metal substrate surface, causing a reduction of the metal in the passivating oxide film. The reduced metal ion (e.g., Fe), then migrates into the glass structure and the Co forms a CoO layer at the interface. Therefore, the composition of the enamel may not be in equilibrium until some later time. This may cause the damping properties of the glass to change slightly during repeated testing at high temperatures. Also, all of the Co will not be consumed at the interface, causing the remaining Co to act as a modified ion, resulting in the lower loss modulus observed with increasing Co_2O_3 additions.

4.1 DISCUSSION

Glass structural considerations and factors influencing performance of the vibration damping glass coating led to an experimental design in which amounts of Al_2O_3, Na_2O and Co_2O_3 were varied. Major factors of consideration influencing the glass coating were: (1) the viscosity-temperature relationship, (2) the metal-glass interface chemistry, (3) the thermal

expansion coefficient, (4) the elastic modulus, and (5) the chemical durability. The experiment was intended to determine the effects of the compositional variation on the five major factors. Results of the experiment are presented in the graphic form from Figure 65 to 75 and in the tabular form in Table 30. In this section an attempt will be made to explain and account for the variation in the glass coating's damping properties, with particular emphasis on the loss factor (η) as it is directly related to the vibration energy dissipated.

4.1.1 Loss Factor Peak Temperature versus Tg

Figure 74 shows a relationship between the loss factor peak temperature at 100 Hz and the glass transition temperature (Tg). The glass transition temperature represents the temperature at which extrapolated low and high temperature linear portions of the thermal expansion curve intersect. It is obvious from the figure that increasing Tg increases the peak temperature. This suggests that the loss factor peak temperature is determined by the viscosity of the glass because Tg corresponds to a given viscosity (approximately $\eta = 10^{13}$ poise). An estimation of the viscosity corresponding to the peak temperature can be made. The viscosity data for Corning 0010 glass are available and are shown in Figure 75. The loss factor peak temperature for the Corning 0010 glass at 100 Hz is 650°C (Table 29) which corresponds to a viscosity of 10^7 poise. Similarly, for 1,000 Hz, the loss factor peak corresponds to $10^{6.5}$ poise. It is, therefore, noted that the observed damping occurs when the glass temperature is near the softening point ($\eta = 10^{7.6}$).

In regard to the effect of compositional variation on Tg, it is noted that: (i) increasing Al_2O_3 in the glass increases its glass transition temperature, (ii) increasing Na_2O decreases the glass transition temperature, and (iii) variations in Co_2O_3 do not show a significant effect on the Tg. The effects of Al_2O_3 and Na_2O are consistent with the glass structural theory described earlier in this report. Classified as an intermediate,

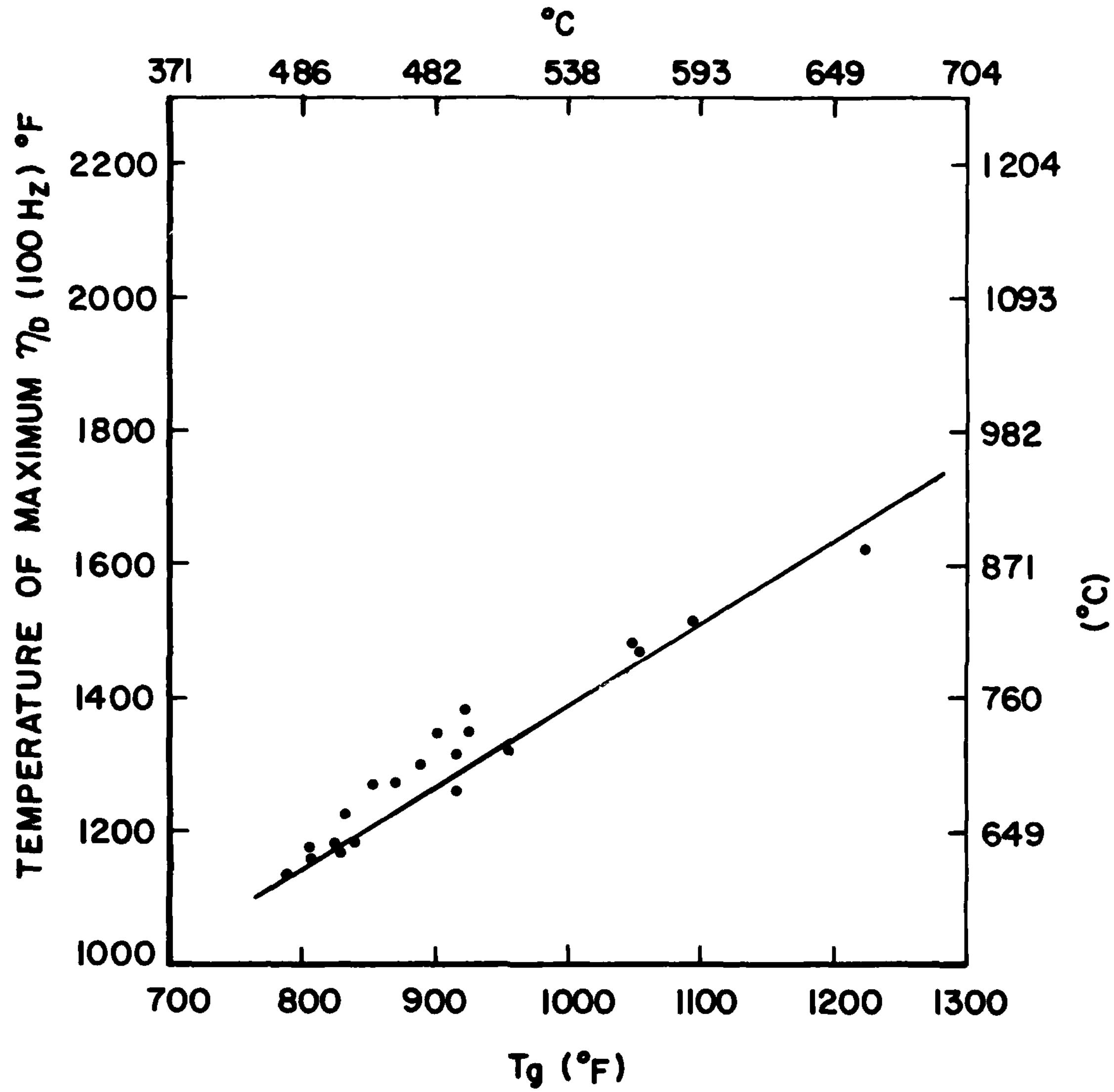

Figure 74. Loss Factor Peak Temperature Versus Glass Transition Temperature for Corning 0010 with Various Additions.

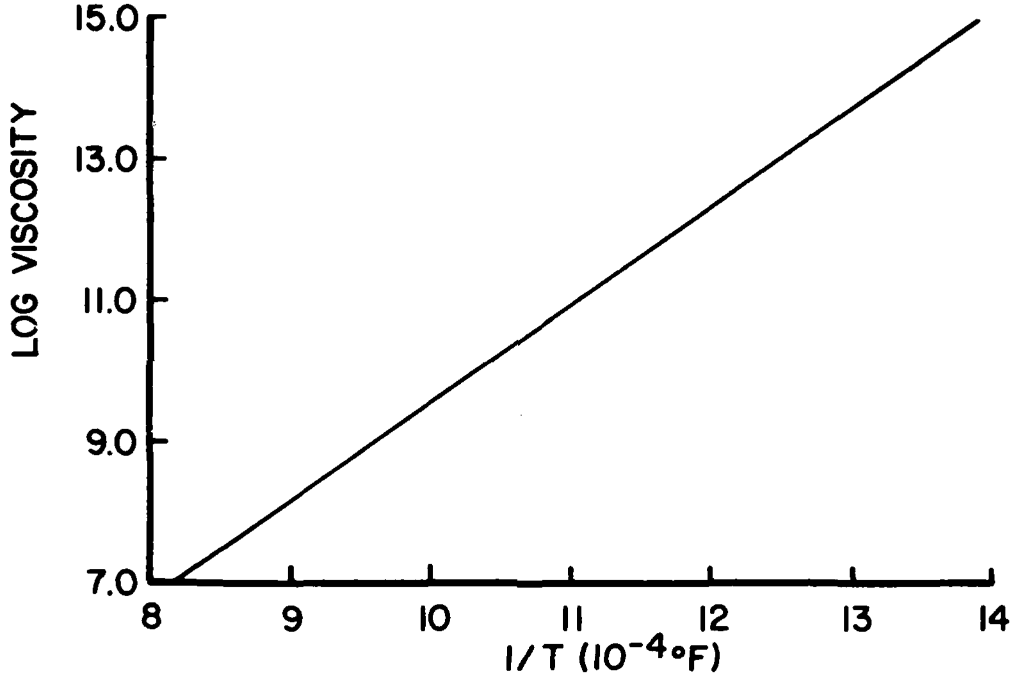

Figure 75. Viscosity Versus Temperature for Corning 0010 Glass.

Al_2O_3 provides 1.5 oxygen per aluminum ion. By virtue of its ability to participate in the network and being a source of oxygen, it converts the non-bridging oxygens to bridging oxygen in the glass structure. This process makes the structure rigid and increases the viscosity over the entire temperature range. The increase in the glass transition temperature with increasing Al_2O_3 reflects this rigid nature of the glass structure. The effect of increasing Al_2O_3 on Tg is shown in Figure 76. The sodium oxide provides 0.5 oxygen per sodium ion and therefore helps in increasing the concentration of non-bridging oxygen in the glass structure. This is evidenced by a decrease in the Tg. In general, the effect of Na_2O is to decrease the viscosity over the entire temperature range for most glasses.

4.1.2 Loss Factor Peak Height

Addition of Al_2O_3 also progressively decreases the loss factor peak height as shown in Figure 77. This can be explained on the basis of structural changes caused by the Al_2O_3. There are two factors which determine height of the damping peak, namely: (i) the concentration of the relaxation units and, (ii) temperature distribution of the relaxation periods. The Al_2O_3 addition decreases the number of relaxation units by converting the non-bridging oxygens to the bridging oxygen. It is believed that non-bridging oxygen is one of the contributors to the relaxation process. Progressive addition of Na_2O increases the damping peak height. This is expected in view of the explanation provided for the effect of Al_2O_3. Na_2O, being a modifier, generated more non-bridging oxygen and also provides a very mobile species, Na, in the glass. These two i.e. increased concentrations of non-bridging oxygen and sodium are expected to increase the number of relaxation units. The effect of cobalt oxide on the loss factor peak height is insignificant.

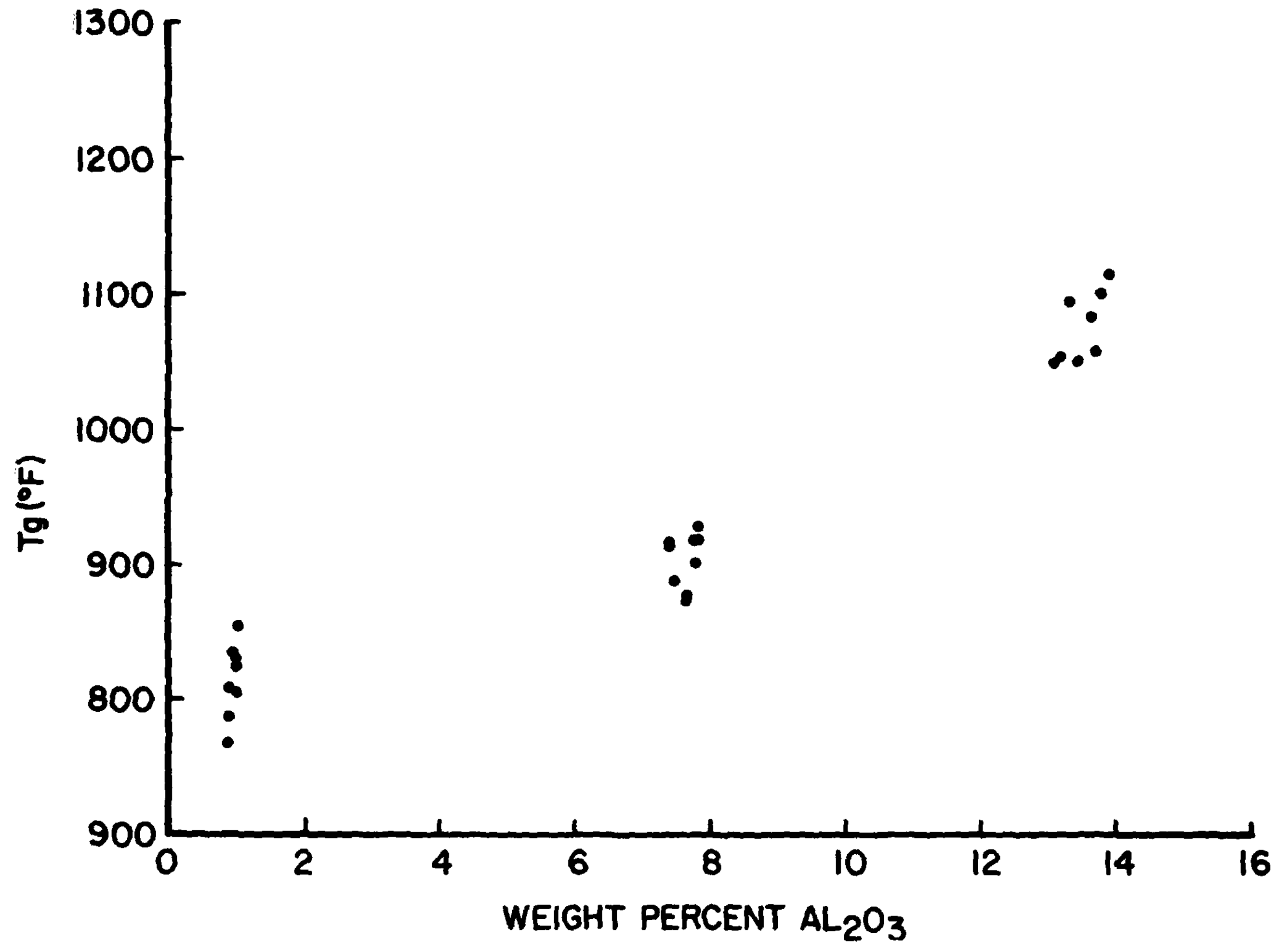

Figure 76. Effect of Al_2O_3 Additions on the Glass Transition Temperature of Corning 0010 Glass.

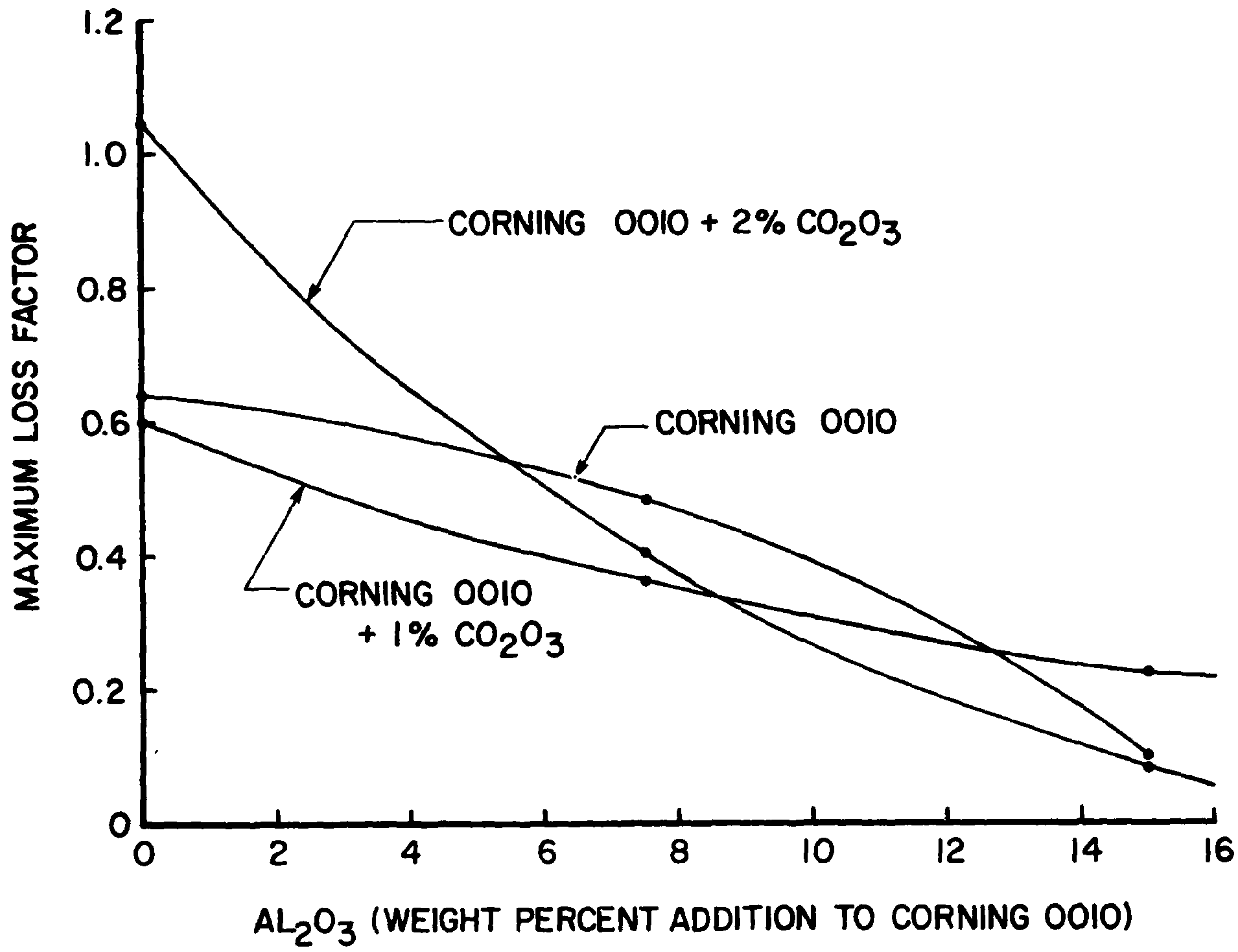

Figure 77. Effect of Al_2O_3 Additions on the Loss Factor Peak Height of Corning 0010 Glass.

4.1.3 Activation Energy for the Relaxation Process

An estimation of the activation energy for the relaxation process can be made using the relationship as expressed by the equation (6).

$$\omega_1\tau_1 = \omega_2\tau_2 \tag{6}$$

$$\text{or,} \quad \frac{\omega_2}{\omega_1} = \frac{\tau_1}{\tau_2} = \frac{\tau_o\, e^{\Delta H/RT_1}}{\tau_o\, e^{\Delta H/RT_2}} \tag{7}$$

$$= e^{\frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} \tag{8}$$

$$\text{or,} \quad \ln \frac{\omega_2}{\omega_1} = \frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \tag{9}$$

Where: ω_1 & ω_2 = natural frequencies at 100 Hz and 1,000 Hz

τ_1 & τ_2 = relaxation times at frequencies 100 Hz and 1,000 Hz

T_1 & T_2 = temperatures corresponding to peaks for 100 Hz and 1,000 Hz

ΔH = activation energy for the relaxation process

R = gas constant.

Provided for each composition in Table 29 are maximum loss factors (η_D) for temperatures corresponding to frequencies of 100 Hz and 1,000 Hz. This information can be used in equation (9) to determine the activation energy for the relaxation process. Activation energies obtained for each composition are shown in Table 30. The activation energy for the process ranges from 43.5 to 91.5 kcal/mole. This activation energy is similar to the activation energy required for the viscous flow in glasses.

It is conceivable that the structural units which determine and control the viscous flow also participate in the relaxation or damping process.

4.1.4 Thermal Expansion

The coefficient of thermal expansion remains relatively unaffected by the variation in the Al_2O_3 concentration. Progressive addition of Na_2O increases the thermal expansion significantly. Variations in the coefficient of thermal expansion for the glass compositions studied were from 7.9×10^{-6} to 11.0×10^{-6} per degree C. Such a variation in the thermal expansion has not caused any noticeable glass-to-metal adhesion problems. The effect of Co_2O_3 variation on the thermal expansion is insignificant.

APPENDIX A

TESTING PROCEDURE

The cantilever beam test specimen was placed in the damping apparatus illustrated in Figure 5. As mentioned previously, this apparatus compensates for the thermal expansion and high temperature creep of the fixture and damping bolts and insures a constant clamping pressure over the entire temperature range for which the measurements are obtained. The frequency response and modal damping as a function of temperature for each test beam was measured before a damping coating was applied. This was done to obtain accurate resonant frequency measurements of the uncoated beam. Accurate measurements of the resonant frequencies are necessary because the material damping properties calculated from experimental measurements are very sensitive to errors in the ratio of the coated beam resonant frequency to the uncoated resonant frequency (f_{1n}/f_n), especially for thin coatings.

The environmental chamber used for these tests was a three-zone furnace capable of heating the test beams to 950°C (1,750°F). Individual temperature control of each of the zones insured a good temperature distribution over the specimen. Proportional temperature controllers were used which supply energy to the individual zones to balance the heat loss in each zone. The temperature difference over the specimen was maintained at ± 5°F at each temperature. A control thermocouple was placed in each zone and four measuring thermocouples placed at different locations along the beam: one at the root of the beam; two in the middle zone; and one at the end zone. These measuring thermocouples were in contact with the beam and the control settings of the individual temperature controllers were adjusted until the temperature distribution along the beam was within ± 3°C. The measuring thermocouples, except for the one in the root of the beam, were lifted off the beam before the dynamic response measurements were made.

For the uncoated beams, each beam was stabilized at the highest expected test temperature (usually about 1,000°C) and the resonant frequency and modal damping of the second through sixth modes were measured. The temperature was then reduced in approximately 100°C increments, stabilized, and the response measurements repeated. This procedure was continued to approximately 300°C. The resonant frequency and modal damping versus temperature for each of the modes were then plotted. The resonant frequency versus temperature curve for each of the modes of the uncoated specimens tested was a smooth curve, and accurate resonant frequencies could be picked from this curve for any temperature of interest. The modal damping was determined by measuring the half-power bandwidth of each of the modes ($\eta = \Delta f_n/f_n$).

Experience showed it was necessary to heat the specimen to the highest temperature and measure the response of the specimen as it was cooled. The resonant frequencies measured on cooling from the highest temperature were higher than the resonant frequencies measured upon heating from room temperature to the highest temperature of interest. Once the specimen was heated to the highest temperature and cooled, the differences in the resonant frequencies measured going up in temperature and those measured coming down in temperature were the same, within experimental error, as long as the specimen was not removed from the fixture. Other investigators (14) have also noticed this behavior. It is believed to be caused by the beam "setting in" the fixture and the relief of surface stresses in the beam introduced during fabrication. It is not due to the beam material being annealed. The annealing temperature of the beam material used (Haynes Alloy 188) is greater than 1,100°C.

After the uncoated specimen response was measured the beam was then coated on one side with a glass. A different beam was used for each of the glass compositions tested. If the same glass composition had to be retested, the coating was removed from the beam, the bare beam was retested, and the same coating

was reapplied to the beam. The coated beam, for these tests, was heated to approximately 750°C (1,400°F) and the resonant frequencies and modal damping of the second through sixth modes were measured. The temperature was then reduced in steps of 25°C and the response was again measured. If the modal damping decreased upon cooling, the temperature of the specimen was increased in 25°C increments until the modal damping decreased for two successive increases in temperature. The specimen was then cooled in 25°C steps and the measurements made again.

The measurements made upon heating were not used to calculate the damping properties of the coating for the reasons previously mentioned. Another reason was the fact that a glass is sensitive to its previous thermal history, in particular to the rate at which it is cooled from its firing temperature. The specimens tested were fired at approximately 1,050°C for five minutes and then air quenched. This rapid cooling may have caused large residual stresses and some non-equilibrium structure to be frozen in. Heating the glass above its softening temperature and slowly cooling allowed the residual stresses to be relieved and the glass to maintain equilibrium.

The loss factor of the uncoated beam was subtracted from the measured loss factor of the coated beam to obtain a "corrected" modal damping coefficient. Sridharan (15) has shown that for small modeled damping,

$$\eta_c = \eta_s - \eta_b$$

where

η_b = modal damping of the uncoated beam

η_s = measured modal damping of the coated specimen

η_c = modal damping that would have been observed if the uncoated beam damping were zero.

This correction is usually only necessary for temperatures greater than 650°C (1,200°F).

The data recorded for each of the modes and temperatures are:

T - the temperature of the specimen

f_n - the resonant frequency of the specimen for the nth mode

Δf - the half-power bandwidth of the nth mode

$\eta_{s/b}$ - modal damping of the nth mode of the coated/uncoated specimen at the length, thickness of the bare beam, average thickness of the coated beam, and the densities of the beam and coating.

APPENDIX B

CURVE FITTING PARAMETERS

The following equations (1-4) were used to fit curves to the vibration damping data versus temperature and frequency. Table 1 contains the values for the parameters of these equations.

$$\mathrm{Log(M)} = \mathrm{Log(ML)} + \frac{2\ \mathrm{Log}\left(\frac{\mathrm{MROM}}{\mathrm{ML}}\right)}{1 + \left(\frac{\mathrm{FROM}}{\mathrm{FR}}\right)^{N}} \tag{1}$$

$$A = \frac{\mathrm{Log(FR)} - \mathrm{Log(FROL)}}{C} \tag{2}$$

$$\mathrm{Log(ETA)} = \mathrm{Log(ETAFROL)} + [(S_L + S_H)A + (S_L - S_H)(1- 1+A^2)]\ \frac{C}{2} \tag{3}$$

$$\mathrm{Log(FR)} = \mathrm{Log(F)} - \frac{12(T - T_o)}{\frac{525}{1.8} + T - T_o} \tag{4}$$

where:

M is the Young's Modulus E'_D

ETA is the Material Loss Factor η_D

FR is the Reduced Frequency $f\alpha_T$

TABLE 1-B

VALUES OF PARAMETERS FOR EQUATIONS 1 THROUGH 4

Matrix Number	T_o	FROM × 10^4	MROM × 10^{-9}	N	ML × 10^{-8}	ETA FROL	S_L	S_H	FROL × 10^3	C
1	600	150.0	14.85	0.61	56.6	0.48	0.45	-0.4	10.0	0.6
2	450	108.9	31.4	1.28	217.0	0.308	0.667	-0.374	3.73	0.124
4	550	0.13	8.4	0.539	15.5	0.27	3.0	-0.325	0.08	0.8
5	550	480.54	5.0144	0.683	7.6632	1.05	0.43	-0.33	20.846	0.25
6	500	85.00	7.0	0.63	13.0	0.85	0.42	-0.46	7.0	0.58
7	500	803.8	14.3	0.727	55.05	0.561	0.363	-0.339	31.0	0.425
11	500	80.0	9.7	0.74	26.0	0.35	2.2	-0.56	0.36	1.271
12	450	0.89	18.0	0.54	70.0	0.36	0.42	-0.5	0.09	0.6
14	500	515.6	11.2	0.687	39.4	0.64	0.53	-0.45	30.0	0.3
17	550	28.0	6.5	0.58	10.0	0.6	0.4	-0.44	6.0	0.9
19	440	63.0	11.0	0.92	34.0	0.53	0.46	-0.60	10.0	0.55
21	650	17.0	12.0	0.73	75.0	0.24	0.37	-0.33	1.2	0.40
22	500	1.1	5.0	0.62	7.3	0.58	0.62	-0.62	0.2	0.64
24	500	0.7	7.0	0.77	14.0	0.58	0.58	-0.54	0.097	0.30
* 27	540	1.3	10.0	0.48	19.0	0.40	0.50	-0.58	0.6	0.90
29	600	3.15	13.1	0.447	57.0	0.30	0.33	-0.33	0.07	0.655
30	500	105.32	13.0	0.748	41.342	0.64	0.40	-0.37	9.0	0.224

TABLE 1-B (Continued)
VALUES OF PARAMETERS FOR EQUATIONS 1 THROUGH 4

Matrix Number	T_o	FROM × 10^4	MROM × 10^{-9}	N	ML × 10^{-8}	ETA FROL	S_L	S_H	FROL × 10^3	C
31	550	34.0	7.4	0.68	15.0	0.90	0.43	-0.42	2.5	0.230
32	540	4.1	7.8	0.63	22.0	0.47	0.49	-0.47	0.505	0.43
35	550	63.0	10.1	0.72	32.0	0.63	0.52	-0.43	3.9	0.24
36	600	8.0	22.0	0.68	170.0	0.10	0.35	-0.275	0.21	0.50
41	550	1.0	18.2	0.63	94.2	0.18	0.40	-0.41	0.041	0.59
45	500	38.911	10.78	0.745	33.602	0.59	0.72	-0.52	1.8	0.510
46	550	8.0	13.5	0.90	56.0	0.44	0.48	-0.52	0.5	0.370
48	550	6,500.0	9.8	0.55	33.0	0.642	0.363	-0.357	642.29	0.561
49	550	83.6	10.0	0.55	34.7	0.42	0.42	-0.42	11.8	0.52
*26	500	97.694	9.6895	0.582	2.5663	0.66	0.5	-0.6	10.0	1.00

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